THE SIXTH GEOLOGICAL SURVEY

WILLARD ROUSE JILLSON

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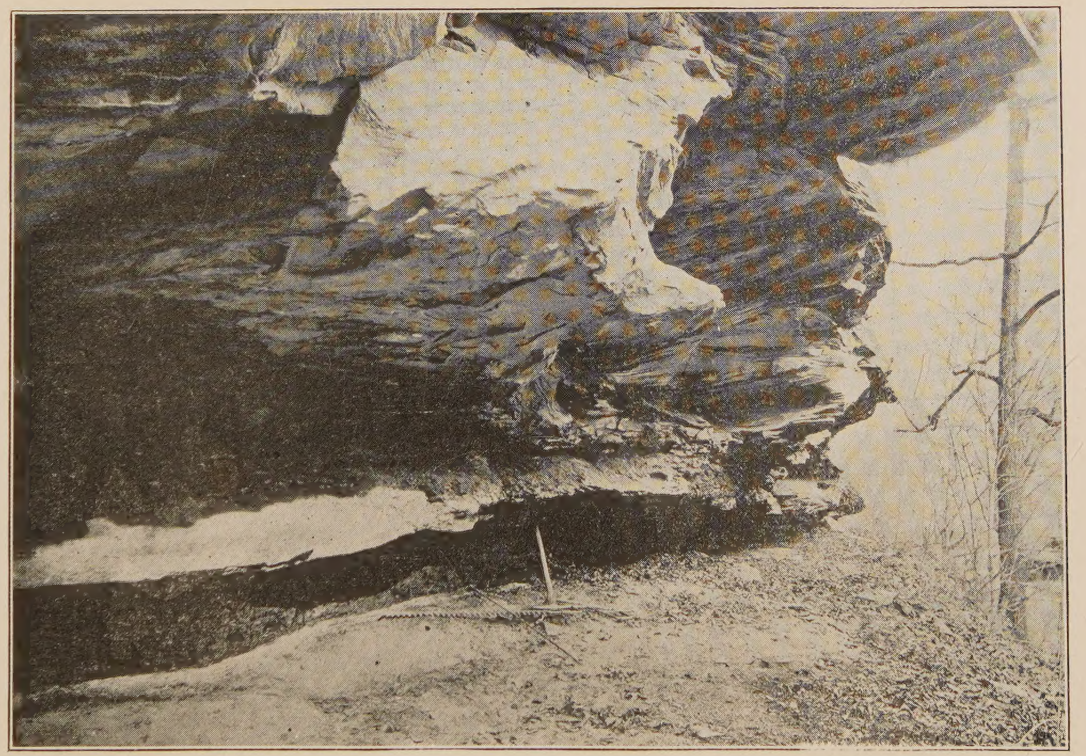
The

Kentucky Geological Survey

WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

SERIES SIX
VOLUME SIX

The Sixth
Geological Survey
1921



THE WHITESBURG COAL AND SANDSTONE "ROCKHOUSE" ROOF.

This characteristic view of the well known Whitesburg coal and its superimposed thirty feet of cliff forming sandstone may be seen on Otter Creek just above its juncture with the Middle Fork of the Kentucky River in Perry County.

THE SIXTH GEOLOGICAL SURVEY

An Administrative Report of the Several Mineral Resource and General Geological Investigations Undertaken and Completed in Kentucky during the Biennial Period 1920-1921

By

WILLARD ROUSE JILLSON

DIRECTOR AND STATE GEOLOGIST

PRESENTED WITH TEN SEPARATE MISCELLANEOUS GEOLOGICAL PAPERS

BY

GEORGE P. MERRILL,
STUART WELLER
WILLARD ROUSE JILLSON
STUART ST. CLAIR
AND
CHARLES STEVENS CROUSE

Illustrated with 101 Photographs Maps and Diagrams

First Edition

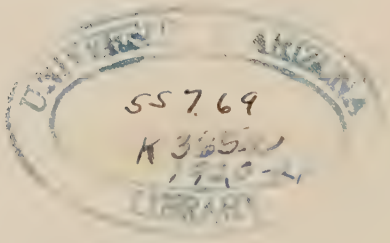
1,000 Copies

THE KENTUCKY GEOLOGICAL SURVEY

FRANKFORT, KY.

1921

THE STATE JOURNAL COMPANY
Printer to the Commonwealth
Frankfort, Ky.



PREFACE

Applied geology is of great economic value to every State in which natural resources are only partly developed. This is especially true of Kentucky where the great body of mineral resources are now less than 20% under commercial operation. An ideal arrangement would be one where the State would have completed the base (topographic) mapping and the preliminary geological-resource surveys prior to the opening up of any oil, coal, natural gas, asphalt or other field. During the period of proving up such a field, State employed geologists could well work hand in hand with the operators, and assist them greatly in their efforts to win the resources desired.

Unfortunately this ideal arrangement has never existed in Kentucky, though it has to some extent in other States. With only 46% of Kentucky base (topographic) mapped, and with an area approximating that of sixty counties not covered by any accurate maps at all, the function of the Kentucky Geological Survey has always been crippled and held in restraint. The day of a 100% efficiency of the Kentucky Geological Survey seems yet to be in the distant future.

During the last biennium a large number of subjects of great economic value to this State have been investigated, however, by the Kentucky Geological Survey. A full account of these investigations is presented herewith in the first paper of this volume entitled, "The Sixth Geological Survey." A number of these economic papers are included within the covers of this book, and should assist materially in an understanding of the geology and resources of the several regions covered. This report is issued in an original edition of one thousand copies.

W. R. Jillson

Director and State Geologist.

Old Capitol,
Frankfort, Kentucky.
December 15, 1921.

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The Sixth Geological Survey

I

THE SIXTH GEOLOGICAL SURVEY

(Years of 1920 and 1921)

AN ADMINISTRATIVE REPORT

BY

WILLARD ROUSE JILLSON

DIRECTOR AND STATE GEOLOGIST

ORGANIZATION.

The General Assembly of Kentucky in its regular Session of 1920 passed, "An Act abolishing the Department of Geology and Forestry, the office of Commissioner of Geology and Forestry, the office of Deputy Commissioner of Geology and Forestry, the offices of State Forester, and State Geologist attached thereto, and all other offices, officers, deputies, assistants, clerks, etc., pertaining to the Department of Geology and Forestry as provided for in chapter 35, Acts of 1918, and chapter 59, Kentucky Statutes, Carroll, Vol. 3, 1918, section 2007a—1 to 2007g—31, inclusive, and to empower the Commissioner of Agriculture, Labor and Statistics to employ necessary clerks, stenographers and laborers, and to appoint a forester, fixing his salary, to appropriate funds for the purpose of carrying out the provisions of this Act and allowing co-operation with the Game Department, and declaring an emergency to exist. H. B. 253—Lazarus[1]. It also passed, "An Act creating the Kentucky Geological Survey, designating its executive officer and his duties, and providing funds for its maintenance. H. B. 261—Stewart, R. L.

Governor Morrow approved these bills on March 20, 1920, which act officially reorganized the (Sixth) Kentucky Geological Survey. On April 1st the Governor appointed Willard Rouse Jillson, Director and State Geologist of the new Kentucky Geological Survey, and this important though little

[1]Chapters 33 and 34 of the Acts of the General Assembly of the Commonwealth of Kentucky, 1920.

understood department of the State Government began to function immediately.

Governing Statute.

The Act creating and governing the (Sixth) Kentucky Geological Survey and making appropriations for same follows:[2]

"AN ACT creating the Kentucky Geological Survey, designating its executive officer and his duties, and providing funds for its maintenance.

Be it enacted by the General Assembly of the Commonwealth of Kentucky:

1. Established.—That the Kentucky Geological Survey is hereby created and established, with a single executive officer, who shall be designated as the Director and State Geologist; that the offices of said survey shall be at the seat of government, Frankfort, Ky.; that the geological collections, records, maps, reports and accumulated property of former Kentucky Geological Surveys, excepting the collections of the State Museum, be, and the same are, hereby to be maintained at the offices set aside for said Kentucky Geological Survey, at Frankfort, Ky., and the money necessary for their maintenance and for the maintenance of said survey is hereby appropriated from any money in the State treasury not otherwise appropriated.

2. Director and State Geologist.—Appointment.—Qualification.—Term. That the Governor shall, with the advice and consent of the Senate, appoint a technically trained geologist as Director and State Geologist of the Kentucky Geological Survey, who shall have a thorough, scientific, and practical knowledge of the sciences of geology, mineralogy, hydrography, and allied subjects. Said appointee shall be possessed of at least six years' collegiate and technical training in geology, and shall be a graduate in geology from a recognized university. Said Director and State Geologist shall make his home in Frankfort, Kentucky. He shall enter upon the

[2]Chapter 34, page 141, Acts of the General Assembly of the Commonwealth of Kentucky, 1920. Approved March 20, 1920.

duties of his office immediately upon the enactment of this statute, and shall hold his office for four years, unless removed sooner by the Governor for inefficiency, incompetency or misconduct.

3. Duties of Director and State Geologist.—Reports by.——It shall be the duty of the Director and State Geologist to give his attention to the administration of the affairs of the Kentucky Geological Survey; to visit any and all parts of the State so as to make himself familiar with the needs of each section; to supervise, outline and edit the work of his assistants; to advance the interests of Kentucky by presenting in person, or otherwise before national geological meetings, authoritative statements of the geological and mineral resources of the State; to undertake such field work as his time will permit, and to perform such other duties as may properly pertain to his office. He shall have the supervision of the entire work of the survey, and shall be responsible for the accuracy of same. He shall make a brief report biennially to the Governor on January 1st, at the convening of the State General Assembly, covering the activities accomplished by and proposed for the Kentucky Geological Survey. He shall devote his entire time to the above duties as hereinbefore set out. Under the direction and control of the Director and State Geologist, the corps of the survey shall proceed to make careful geological, mineralogical, chemical, physical and soil surveys of the State; to enter upon record an accurate statement of the extent of water power and water courses, to locate coal, oil, metalliferous deposits, clays, ores, building stones, etc., etc., to report characteristics and compositions of soils and minerals; to collect, analyze, classify and label specimens of rocks, fossils, ores, coals, oils, gases, minerals, soils and other natural resources of the State; to cause specimens of the above named exhibits of the State to be correctly labeled and preserved in the museum of the State University at Lexington and in the office of the Geological Survey at Frankfort.

4. Assistants.—Expenses to be Reported.—The Director and State Geologist is authorized to employ competent assistant geologists, paleontologists, topographers, surveyors, spe-

cialists and such stenographic assistants as may be required for the proper conduct of the affairs of the survey. All traveling and field expenses of the director and his assistants, and all expenses of the Kentucky Geological Survey shall be itemized each month, and if approved by the director shall be forwarded to the auditor, who shall draw his warrants for the various amounts from funds appropriated for the maintenance of the Survey. Payment of any item of expense connected with the survey shall not be made until the approval of the director is secured in writing.

5. To Co-operate with the United States Departments.—The Director and State Geologist may enter into co-operative arrangements for geological, topographic, soil and such other surveys as are properly within the scope of the Kentucky Geological Survey, with the State Experiment Station, United States Geological Survey, the United States Department of Agriculture, or other organization of governmental departments; provided, that in each case agreed upon the said organization or department shall furnish an amount of money equal to that allotted for such work by this survey; and provided, further, that such co-operative agreements shall be made and carried out so that in all things they will prove advantageous to the State of Kentucky.

6. Salary.—The salary of the Director and State Geologist shall be $3,000 per annum, which sum is hereby annually appropriated from any money in the State treasury not otherwise appropriated, and is in addition to the annual appropriation made for the Kentucky Geological Survey.

7. Equipment to be Furnished.—It shall be the duty of the Commissioner of Public Printing to supply the Kentucky Geological Survey with all necessary stationery, accessory printing, printing of reports and maps, etc., in the same manner as all other state offices are supplied, upon the signed requisition of the director of the survey, and with the approval of the Printing Commissioners or similar body.

8. Reports.—Concerning.—The reports of the survey shall be prepared as rapidly as possible, and shall be reviewed, edited and approved by the director, who shall requisition

the printing of same through the Commissioner of Public Printing, the cost thereof to be paid out of the general expenditure fund as in the case of other official reports. The director is authorized to publish in the daily and weekly newspapers, trade journals, geological magazines or in pamphlet form any geological discoveries or results of especial interest, the cost of such publications, if any, to be paid out of the general expenditure fund not to exceed the sum of five thousand dollars. No reports or maps prepared by the Kentucky Geological Survey shall be sold, but nominal charges to cover postage may be made, and all stamps when so received shall be kept and reused without itemization by the survey.

9. Appropriation.—For the purpose of carrying into effect the provisions of this Act, there is hereby appropriated the sum of $15,000.00 annually for the geological, chemical, technical, soil and other investigations authorized by this Act, including all salaries and field expenses, clerical assistance, laboratory, field equipment, supplies, freight charges, and all necessary miscellaneous items of permanent improvement to the property and effects of the Kentucky Geological Survey; and the further sum of $12,500.00 annually for topographical surveys in co-operation with the United States Geological Survey, subject to the provisions of Section 5, of this Act; provided, that in the event it should at any time prove that said co-operative work is not being conducted to the best advantage to the State, the Director of the Kentucky Geological Survey is hereby authorized to withdraw from such co-operation, when so advised by the Governor, and the mapping may be continued by the Kentucky Geological Survey alone, or the unexpended balance be turned back into the treasury and the appropriation for said co-operative surveys cease or be used for such other purposes of the survey as the director may indicate.

10. Emergency.—Whereas, the law relating to the Department of Geology and Forestry has been repealed at this session of the General Assembly, thereby setting aside any and all appropriations belonging to geological research in this State,

and whereas, there are now no funds available for this work or to support the Geological Survey, herein provided for, an emergency is declared to exist, and this Act and its appropriations shall, therefore, go into effect immediately upon its approval by the Governor.

Approved March, 20, 1920.

EDWIN P. MORROW, Governor."

PREVIOUS SURVEYS.

The work of mapping the geology and the mineral resources of Kentucky was begun under the official act of the State in 1838, when by legislative action Dr. William Williams Mather, of Albany, New York, made the first reconnaissance survey of Kentucky. This report was published in 1839 as a legislative paper.[3] Although a State-wide survey with adequate appropriations was outlined in Mather's report, no actual Kentucky Geological Survey was provided for by legislative enactment until 1854, when the first survey under the leadership of Dr. David Dale Owen, of New Harmony, Indiana, was organized by legislative enactment. This survey functioned until the death of Dr. Owen in 1859, its last publication, Vol. IV of the Series I, appearing in 1860.

An hiatus during the time of the Civil War was followed by the reorganization of the (Second) Kentucky Geological Survey in 1873 under the direction of Dr. Nathaniel Southgate Shaler, of Newport, Kentucky, and Cambridge, Mass. The Shaler survey terminated with the resignation of its Director in 1880, and was followed by a slight reorganization in 1880 so as to include the Bureau of Immigration, and Mr. John Robert Procter, of Maysville, Kentucky, formerly an assistant of Dr. Shaler, was made the Director. During the Procter term, which continued up to the abolishment of the Kentucky Geological Survey in 1892, this organization was commonly known still as the (Second) Kentucky Geological Survey.

A widespread lapse of interest in the mineral and geological development of Kentucky, at this time, became responsible for the second lengthy period during which nothing was done

[3]Pp. 239-278 Ky. House of Rep. Jour., 1838-39.

by the State to assist in geological investigations within its borders. The General Assembly of 1904 became convinced of the shortsightedness of this program for a State as rich in mineral deposits as Kentucky, and reorganized at its regular session of 1904 the (Third) Kentucky Geological Survey. Prof. Charles Joseph Norwood, of Lexington, Kentucky, the then State Inspector of Mines, was made Director and State Geologist by legislative enactment. This survey functioned until 1912, when shortly following the opening of the McCreary administration a Bill was introduced which in effect abolished the Norwood survey, and created the (Fourth) Kentucky Geological Survey. Mr. Joseph Bernard Hoeing, of Lexington, Kentucky, an Engineer and Geological Assistant on the several Shaler-Procter-Norwood Surveys, was appointed State Geologist.

The Fourth Kentucky Geological Survey functioned until 1918, when again by shortsighted methods and means political, it was combined with the State Board of Forestry, the appropriations for which had been entirely withdrawn. Under the new title of the Office of Commissioner of Geology and Forestry this the (Fifth) Kentucky Geological Survey, which later became known generally as the Department of Geology and Forestry, functioned until March 20, 1920. For this fifth Survey Mr. John Earle Barton acted as Commissioner and State Forester, and Prof. Willard Rouse Jillson as Deputy Commissioner and State Geologist, both under appointment of Gov. A. O. Stanley. Chapter 33 of the Acts of the General Assembly, 1920, abolished this department, and recreated the (Sixth or Present) Kentucky Geological Survey, which by reason of the emergency clause carried in the creating Act, began to function April 1, 1920, with the appointment by Gov. Edwin P. Morrow of the present Director and State Geologist.

PERSONNEL OF THE (SIXTH) KENTUCKY GEOLOGICAL SURVEY.

Following upon the reorganization of the (Sixth) Kentucky Geological Survey, the following personnel of scientific assistants and trained office workers was established during 1920

and 1921. The most of these assistants are known as "temporary employees," having been engaged for a summer field season of two or three months to do a special piece of geological or mineral resource investigation.

Willard Rouse Jillson, B. S., M. S., Sc. D., Frankfort, Ky., Director and State Geologist.
Charles Henry Richardson, Ph. D., Syracuse, N. Y., Assistant Geologist.
Stuart Weller, Ph. D., Chicago, Ill., Assistant Geologist.
Leonidas Chalmers Glenn, Ph. D., Nashville, Tenn., Assistant Geologist.
Heinrich Ries, Ph. D., Ithaca, N. Y., Assistant Geologist.
Walter H. Bucher, Ph. D., Cincinnati, O., Assistant Geologist.
Charles H. Butts, M. S., Washington, D. C., Assistant Geologist.
Louis W. Currier, M. S., Boston, Mass., Assistant Geologist.
Stuart St. Clair, M. A., Winchester, Ky., Assistant Geologist.
Floyd Hodson, A. B., Ithaca, N. Y., Geologic Aide.
James S. Hudnall, B. S., Bowling Green, Ky., Geologic Aide.
Benjamin B. Cox, B. S., Chicago, Ill., Geologic Aide.
H. V. Tygrett, B. S., (?) Bowling Green, Ky., Geologic Aide.
R. A. Jones, B. S., Chicago, Ill., Geologic Aide.
D. H. Davis, A. B., Ann Arbor, Mich., Geographic Aide.
John S. Carroll, Frankfort, Ky., Field Assistant.
A. B. Williams, Frankfort, Ky., Field Assistant.
A. M. Peter, Sc. D., Lexington, Ky., Chemist.
Charles Stevens Crouse, E. M., Lexington, Ky., Draftsman.
Warren R. King, C. E., Chattanooga, Tenn., Water Resource Engineer.
Mrs. James Sadler, Burgin, Ky., River Gauge-reader.
Miss A. L. Brunson, Cumberland Falls, Ky., River Gauge-reader.
Mr. James Carroll, Nevelsville, Ky., River Gauge-reader.
Mr. Chester Williams, Munfordville, Ky., River Gauge-reader.
Mr. J. M. Frasure, Langley, Ky., Secretary and Clerk.
Miss Catherine B. McNamara, Frankfort, Ky., Stenographer and Account Clerk.
Miss Ann M. Crittenden, Frankfort, Ky., Manuscript Copyist.

OUTLINE OF ACTIVITIES IN 1920.

During the first field season, the summer of 1920, a number of important investigations were undertaken. Dr. Richardson carried out a reconnaissance investigation covering the "Glass Sands of Kentucky." He penetrated into each county of the State in which it was known or suspected that commercial glass sands were to be found, with the result that a wealth of information concerning these important but undeveloped minerals in Kentucky was brought together. Dr. Stuart Weller, with Mr. Jones as assistant, mapped the stratigraphic and

structural geology of the Golconda sheet in Livingston and Crittenden Counties, in which is found a portion of the fluorspar district of Western Kentucky.

Dr. Glenn spent a portion of the season in Webster County re-working and revising a report on the Geology and Coals of this county. This report had first been prepared a number of years ago for the Norwood or (Third) Kentucky Geological Survey, but due to misunderstanding had never been published. Dr. Glenn also mapped the stratigraphic and structural geology of Webster County at a scale of one inch to the mile.

Prof. Currier undertook an examination of the fluorspar deposits of the State, and in the summer of 1920 practically completed a report on the fluorspar field of Western Kentucky in Livingston, Crittenden and Caldwell Counties. In the summer of 1921 he finished the work in the Western section, and also completed the field work of an examination of the Central Kentucky fluorspar deposits. Prof. Bucher spent portions of the summer of 1920 and 1921 in mapping the structural and stratigraphic geology of the Jeptha Knobs section in Shelby County, Ky. Charles H. Butts spent the season of 1920 in finishing his stratigraphic and economic examination of the Mississippian series in Southern and Eastern Kentucky.

OUTLINE OF ACTIVITIES IN 1921.

Throughout the past summer a number of greatly needed geological and mineral resource investigations have been carried through to completion. Dr. Ries, assisted by Mr. Floyd Hodson, spent the greater portion of the field season of 1921 in a State-wide examination of the Kentucky clays and shales, and their associated industries. This reconnaissance survey has been completed. Dr. Richardson spent the summer of 1921 in a reconnaissance examination of the "Building Stones of Kentucky," in which he examined every important rock producing county in the State, and brought to light not only a number of new and excellent limestones and sandstones, but about twenty very commercial and heretofore unknown varieties of marble. W. R. King, assisted by Mrs. Jas. Sadler, Mr.

James Carroll, Mr. Chester Williams and Miss A. L. Brunson, Gauge-readers, spent the summer of 1920-1921 in making field examinations and in collecting stream flow data with respect to the "Water Power Resources of Kentucky."

During the past two years, although the time of the Director, Dr. W. R. Jillson, might have been fully taken up in the official administration of the expanded affairs of the Survey, he has found it possible to make personally the necessary field examination and write the manuscript for twenty separate and distinct geological reports within Kentucky. These reports which are now in print, have covered the economic subjects of oil shales, oil and gas, coal, rock asphalt, and fluorspar, as well as several miscellaneous geologic titles. In this work Dr. Jillson has been assisted by Mr. John S. Carroll. Mr. J. S. Hudnall, Mr. H. V. Tygrett, and Mr. A. B. Williams.

During the field season of 1921, Dr. Stuart Weller, assisted by Mr. B. B. Cox, has been engaged in the mapping of the structural geology of the Princeton Quadrangle in the Western Kentucky fluorspar field. This quadrangle includes portions of Caldwell, Lyon, Crittenden and Hopkins Counties. Mr. D. H. Davis has spent the summer of 1921 in regional geographic studies confined to the Jackson Purchase region of Kentucky, which includes Ballard, Carlisle, Hickman, Fulton, McCracken, Graves, Marshall and Caldwell Counties.

TOPOGRAPHIC MAPPING.

During the years 1920-1921 the co-operative topographic mapping agreement between the United States Geological Survey and the Kentucky Geological Survey has been continued, as a result of which $12,500.00 has been devoted to this work by each of these organizations. The designation of the location of the areas to be mapped is vested in the Director of the Kentucky Geological Survey; and the appointment of trained engineers is made by the Director of the United States Geological Survey. As a result of this co-operative agreement, the Golconda Quadrangle in Livingston and Crittenden Counties in Western Kentucky, the Glenmore Quadrangle in Warren, Butler and Edmonson Counties, and the northern half

of the Bowling Green Quadrangle, covering portions of Warren, Simpson and Allen Counties, were finished in the season of 1920. In the season of 1921, the Bowling Green Quadrangle was finished, and the Fords Ferry Quadrangle, including parts of Crittenden, Livingston, Caldwell and Lyon Counties, in Western Kentucky, was completed. In this same season the mapping of the Mammoth Cave Quadrangle, including portions of Edmonson, Warren, Barren and Hart Counties, was undertaken, as was the mapping of the Frankfort Quadrangle, including portions of Franklin, Anderson and Woodford Counties, in central Kentucky. The Frankfort (Special) Capitol City Map, scale of 1-24,000 was also completed and published. The Golconda Quadrangle has been engraved and is now being distributed.

As a result of these topographic surveys which have been continued now for several years, 46.4% of the State of Kentucky was on August 1, 1921, completely mapped. This leaves a balance of 53.6% of the State of Kentucky which has never been mapped, and is more or less imaginary on all maps of the State of Kentucky. The total amount of topographic mapping now completed in Kentucky compares very unfavorably with those sister States of Kentucky which have a similar topography, as the following letter from the Director of the U. S. Geological Survey shows:

"August 27, 1921.

Dr. W. R. Jillson,
State Geologist and Director,
Frankfort, Ky.

My Dear Dr. Jillson:

In reply to your letter of August 22:

The following table gives the percentage of completed topographic mapping in Kentucky, Ohio, West Virginia, Virginia and Tennessee to August 1, 1921:

State	Percentage Completed. August 1, 1921.
Kentucky	46.4
Ohio	100
West Virginia	100
Virginia	84.6
Tennessee	50.6+

Yours very truly,

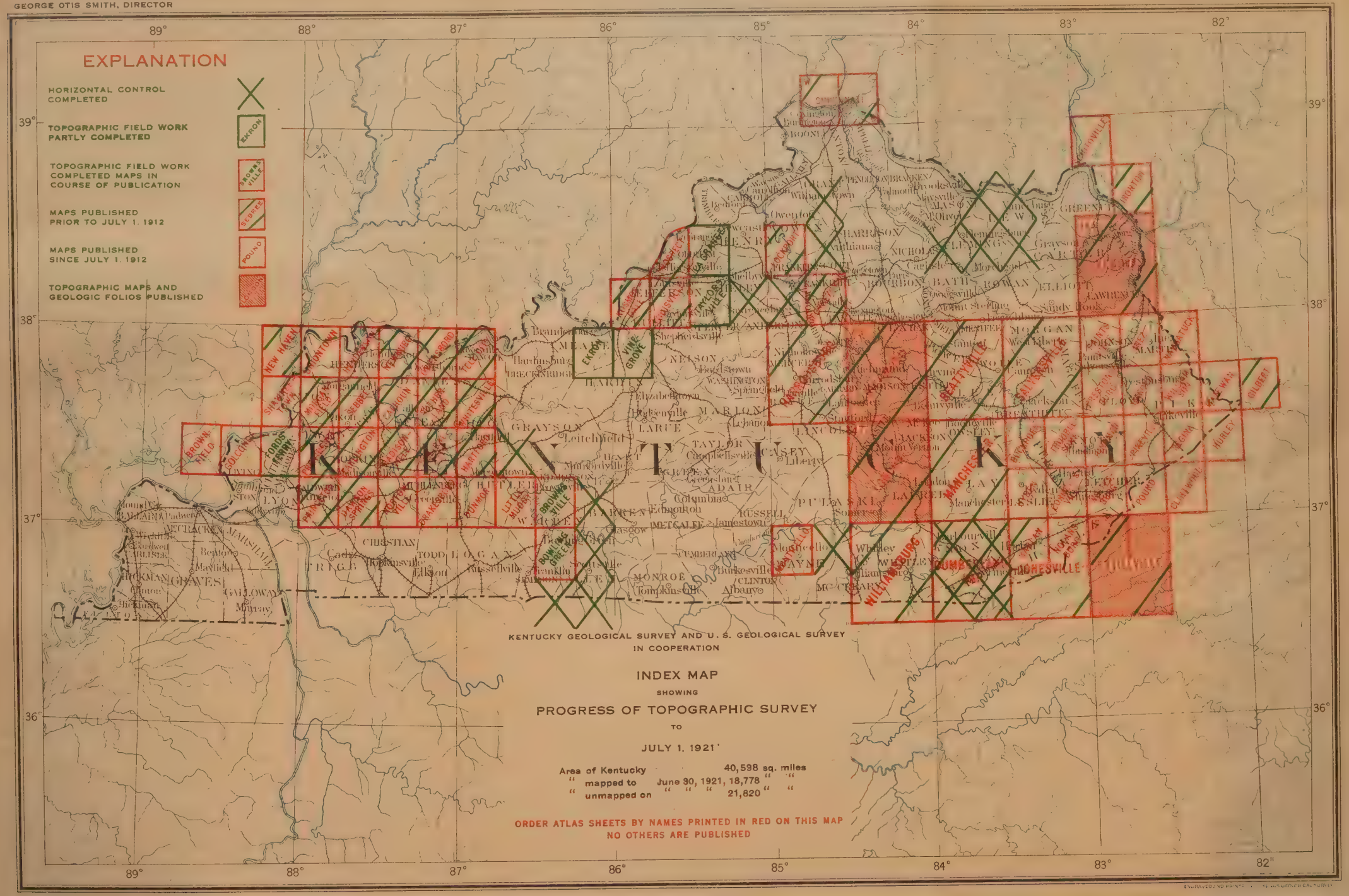
GEO. OTIS SMITH,
Director."

TYPE OF NEW TOPOGRAPHIC MAP.

This is a portion of the new Golconda base map recently published covering parts of Livingston and Crittenden Counties, Ky., and parts of Illinois. The region shown is the largest fluorspar producing area of the United States.

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
U. S GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

KENTUCKY GEOLOGICAL SURVEY
WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST



KENTUCKY GEOLOGICAL SURVEY AND U. S. GEOLOGICAL SURVEY
IN COOPERATION

INDEX MAP
SHOWING
PROGRESS OF TOPOGRAPHIC SURVEY
TO
JULY 1, 1921

Area of Kentucky		40,598 sq. miles
" mapped to	June 30, 1921,	18,778 " "
" unmapped on	" " "	21,820 " "

ORDER ATLAS SHEETS BY NAMES PRINTED IN RED ON THIS MAP
NO OTHERS ARE PUBLISHED

An indexed map showing in colors the number of sheets and the area mapped up to July 1, 1921, is enclosed within this report. A glance at this map will also show the large and important areas of the State which are as yet unmapped.

RESULTS OF INVESTIGATIONS 1920-1921.

Investigations made by the several special and technical assistants of the Kentucky Geological Survey under the leadership of the Director and State Geologist have brought to light many important facts concerning unknown and undeveloped mineral resources of the State of Kentucky.

Dr. Richardson's glass sands investigation in 1920, now published, shows this State to have almost unlimited deposits of glass sands suitable for every known commercial use. It has been found that there are many locations in the State, both in Eastern and Western Kentucky, where deposits of commercially pure glass sands and an abundance of natural gas for fuel purposes in close proximity are located. In Eastern Kentucky this is true of the Big Sandy Valley and the Carter County section. In Western Kentucky, it is true of both Grayson and Hardin Counties. Excellent deposits of glass sands, removed from large fuel supply, but suitable for railroad transportation, have been located near Marion, in Crittenden County, Carrollton, in Carroll County, and many other advantageous points in the State.

Dr. Stuart Weller's mapping of the Golconda sheet, which is a part of the fluorspar area of Western Kentucky and a unit with the Rosiclaire section of Southern Illinois, has shown that region to be extremely faulted. This geologic mapping has opened up a very tempting field for fluorspar prospecting and mine extension work, since it is definitely known that the occurrence of fluorspar in Western Kentucky is associated with the major faults. Prof. Currier's work on the deposits of fluorspar in this State has brought out many new and interesting conditions of occurrence and origin which will materially help the development of this industry in Kentucky.

Dr. Glenn's report on the "Geology and Coals of Webster County" is a thorough and painstaking piece of mapping,

coupled with a discussion of economic geology, which is in reality a distinct contribution to the Kentucky literature. Since Webster County, because of its geographic position, is the key to the Western Coal Field, this report will serve as a guidepost for all future geological work in this portion of Kentucky. The correlation of the coals as outlined by Prof. Glenn will facilitate a better understanding and appreciation of the various seams now commercialized in this region. There can be no doubt but what this report will hasten the development of coal in the Western Kentucky coal field as soon as normal conditions in that industry again obtain.

The work of Mr. Charles H. Butts on the Mississippian series in Eastern and Western Kentucky has been so thorough and so broad in its scope, that it will prove when published a veritable mine of information for the further geological and mineral development of this very large area. While much of the material in this report is of a scientific nature, necessarily, the economic side has not been overlooked. As a result of this fortunate combination, the report teems with information which can be put to excellent commercial use by those who are alert to such values and their industrial application.

Dr. Bucher's work on the Jeptha Knobs section, in Shelby County, Kentucky, while covering a relatively small area, is important, since it will finally establish the geological factors which have operated to produce this singular Blue Grass promontory. This report, which is both structural and stratigraphic, will also throw additional light on the possibilities of securing oil and gas in this section of the State, where the first prospecting, but recently completed, has proven unproductive.

Of the very greatest importance to the present industrial development of Kentucky is the report of Dr. Heinrich Ries on the clays and shales of Kentucky, and their associated industries. Dr. Ries is the ablest American authority on this subject. His report, which will bring together the results of his 3,000 mile reconnaissance in this State, when published, will prove a fundamental source of information. The real im-

portance of this work becomes apparent when it is realized that the clay and shale products industries gave to the State of Kentucky in the year of 1908 a return of $2,239,108. Within ten years this industry trebled itself in Kentucky, for in the year 1918 its total production amounted to the very significant figure of $6,172,554. Investigations made by Dr. Ries show large amounts of excellent pottery, brick, ornamental and roofing tiles, clays and shales in this State, as yet untouched. One of the greatest contributions is the information relative to the immense deposits of undeveloped, and, in a large measure, unknown, fire clays of southeastern Rowan and northwestern Elliott Counties. This deposit of virgin flint fire clay exists south of the known and developed Olive Hill section of Carter County, and suggests that in the future this very poor section of Eastern Kentucky may come to be, from a mineralogical and industrial standpoint, another of its wealthy regions.

Under co-operative agreement with the United States Geological Survey, Water Resource Division, new work has been done and old work continued in the gauging of the principal rivers of this State. Using the data thus obtained, manuscript has now been prepared by W. R. King, District Engineer, United States Geological Survey, for a report on the "Water Power Resources of Kentucky," which it is hoped may be published by the Kentucky Geological Survey in the near future. Demand for this sort of investigation has been greatly increased during the last few years, and this report, since there is nothing of a comprehensive nature on this subject in the Kentucky literature, will prove of much value and benefit to this State.

The work of Prof. D. H. Davis on the "Regional Geography of the Jackson Purchase," that section west of the Tennessee and east of the Mississippi River, including the counties of Ballard, Carlisle, Hickman, Fulton, McCracken, Graves, Marshall and Calloway, will serve a broad use in calling attention to the mineral, agricultural and industrial development of this rich and important westernmost section of the State. The de-

tailed and systematized studies of the industries, the soils and their productivity, the geology and its relation to social and economic development, will prove of great benefit, since it will lead to presenting a clearer and more accurate understanding of the fundamental principles upon which the wealth and prosperity of this region is based.

The personal research work of the Director and State Geologist, Dr. W. R. Jillson, has during the past two years covered a wide field of geological investigation in Kentucky. His reports on oil shale, asphalt, oil and gas, coal, fluorspar, general geology, etc., have been in great demand by the general public, and to such an extent that Vol. II, Series VI, "Economic Papers on Kentucky Geology," in which many of these reports were contained, which was published in May, 1921, in an edition of 2,000 copies, is now rapidly approaching exhaustion, only about 200 remaining at the time of this writing. The necessary field work, followed by the manuscript writing and book-making of these reports, has been completed by the Director in addition to his statutory or official duties as head of the Kentucky Geological Survey. These engagements, coupled with a growing official correspondence, the greater portion of which is of a technical nature, demanding library, experimental or analytical research, has required the very closest application throughout this period. Office hours of the Director have been extended frequently from ten to fourteen hours per day, including Sundays and holidays, in an effort to keep ahead of amassing detail of the Survey organization.

OFFICE WORK.

The office work of this Survey has been carried on with one permanent and one temporary employee, and has totaled 9,549 letters received and 7,060 new letters written and sent out. The average number of letters received per day has been 25, and the average number sent out per day has been a little more than 18. The detail by months and years is given in the following table:

Correspondence through U. S. Post Office at Frankfort, Ky.
(April 1, 1920, to June 30, 1921, inclusive.)

	Letters Received	Letters Sent
1920 (April 1, 1920, to June 30, 1920)		
April	694	325
May	689	438
June	539	463
Total	1,922	1,226
1920 (July 1, 1920, to June 30, 1921.)		
July	525	444
August	473	387
September	544	408
October	598	487
November	609	510
December	519	416
1921		
January	666	468
February	612	410
March	665	383
April	809	968
May	882	451
June	725	502
Total	7,627	5,834
	1,922	1,226
Total, April 1, 1920, to June 30, 1921	9,549	7,060[4]
Daily average	25	18+[4]

PUBLICATIONS SERVICE.

One of the chief activites of the Kentucky Geological Survey is the furnishing of detailed and accurate geological and scientific information concerning the minerals and natural resources of Kentucky. In this State and nation-wide service during the past biennal period 15,326 geological reports and maps have been sent from this office in response to written or personal requests, accompanied by separate amounts of postage as required by law.

[4]The smaller number of letters written and sent out is accounted for by the fact that a considerable portion of the correspondence calls for the sending of particular maps or reports, and does not require other official reply.

Kentucky Geological Survey Publications Distributed Upon Request
(April 1, 1920, to June 30, 1921, inclusive.)

1920	Publications mailed	Publications carried in hand by office visitors	
April	1,103		
May	938		
June	885		
Total (April, May, June, 1920)	2,926	74	
Grand total			3,000
1920			
July	789		
August	942		
September	739		
October	1,127		
November	1,037		
December	1,035		
1921			
January	1,625		
February	793		
March	686		
April	456		
May	1,562		
June	795		
Total (fiscal year 1920-1921)	11,586	749	
Grand total			12,326
Total, Apr. 1, 1920, to June 30, 1921, inclusive			15,326
Daily Average			39+

These reports and maps have covered every known subject relative to the geology, the soils, and mineral resources of this Commonwealth, and have been sent to not only practically every postoffice in the State, but throughout the United States and the world at large. Requests directed from Japan, Australia, Germany and England are frequent. The total amount of postage received in this service and reused directly from April 1, 1920, to August 31, 1921, has amounted to $1,574.08. Since this postage is in effect a revolving unit, being reused as rapidly as it is taken in, amounts in excess of a few dol-

lars are never maintained in this office. Of this considerable postage total, not one penny has been paid by the State of Kentucky in the postal dispatch of these publications, nor the large official correspondence of the Kentucky Geological Survey, during this biennial period.

The monthly and annual totals of the postage stamps received by the Kentucky Geological Survey follow:

Postage receipts from J. P. Noonan, Postmaster, Frankfort, Kentucky, from April 1, 1920, to August 31, 1921, inclusive.

1920		
April	$19.16	
May	44.08	
June	87.92	
July	42.60	
August	75.75	
September	35.10	
October	87.91	
November	72.38	
December	100.55	
Total	$565.45	$565.45
1921		
January	$129.59	
February	44.05	
March	67.91	
April	38.10	
May	130.60	
June	64.20	
July	70.68	
August	49.50	
Total	$594.63	594.63
Postage used in office during year 1920		175.00
Postage used in office during year 1921		239.00
Total amount of postage used from Apr. 1, 1920, to Aug. 31, 1921 incl.		$1,574.08

NEW PUBLICATIONS.

The new publications which have been prepared and issued by the Kentucky Geological Survey are as follows:

Vol. I. "Glass Sands of Kentucky," 149 pages, by Charles H. Richardson, 1920.

Vol. II. "Economic Papers on Kentucky Geology," 304 pages, by Willard Rouse Jillson, 1921. This book contains the following thirteen separate reports:

1. A Preliminary Report on the Oil Shales of Kentucky.
2. Kentucky Rock Asphalt—The Ideal Road Surface.
3. Geological Problems in the Recovery of Oil and Gas in Kentucky.
4. The Production of Kentucky Crude Oils.
5. The Value and Direction of State Geological Surveys.
6. River and Forest Trails in Western Kentucky.
7. The Ultimate Source of Kentucky Crudes.
8. Production of Fluorspar in Western Kentucky.
9. Geology of Oil and Gas in Grayson County.
10. A Mauch Chunk Island in the Mississippian Seas of Eastern Kentucky.
11. The Sandy Hook Anticline—A Newly Discovered Oil and Gas Structure in Elliott County, Ky.
12. The Campbellsville Anticline in Taylor County, Ky.
13. Paint Creek—Pirate.

Vol. VI. "Sixth Geological Survey," by W. R. Jillson and Others, containing the following ten papers:

1. The Sixth Kentucky Geological Survey (Administrative Report 1920-1921), by Willard Rouse Jillson.
2. The Cumberland Falls, Whitley County, Ky., Meteorite, by George P. Merrill.
3. Geology and Coals of The Middle Fork of the Kentucky River near Buckhorn in Perry and Breathitt Counties, Ky., by Willard Rouse Jillson.
4. Oil Pools of Warren County, Ky., by Stuart St. Clair.
5. A New Method of Producing Crude Oil in Ky., by Willard Rouse Jillson.
6. Retorting Methods as Applied to Kentucky Oil Shales, by C. S. Crouse.
7. Oil and Gas Possibilities of the Jackson Purchase Region, by Willard Rouse Jillson.
8. Oil and Gas Possibilities in Caldwell County, Ky., by Stuart Weller.
9. Drainage Problems in Kentucky, by Willard Rouse Jillson.
10. Recent Mineral Production in Kentucky, By Willard Rouse Jillson.
11. The Region About Frankfort, By Willard Rouse Jillson.

The following publications have been completed in their field work and manuscript preparation, and are now in the hands of the printer:

Manuscripts in Press.

Vol. III. "Oil Field Stratigraphy of Kentucky," W. R. Jillson.

Vol. IV. "Geology of the Golconda Quadrangle," Stuart Weller.
Vol. V. "Geology and Coals of Webster County," L. C. Glenn.
Vol. VII. "The Clays of Kentucky," Heinrich Ries.
Vol. VIII. "The Mississippian Series of Eastern Kentucky," Charles Butts.

Manuscripts in Preparation.

The following are incomplete and unlisted manuscripts with tentative titles:

Fluorspar Deposits of Kentucky	L. W. Currier
Building Stones of Kentucky	C. H. Richardson
Geological Research in Kentucky	W. R. Jillson
Mineral Production in Kentucky	W. R. Jillson
Geology of the Princeton Quadrangle	Stuart Weller
Oil and Gas Papers on Eastern Kentucky	W. R. Jillson
Geology of the Jeptha Knobs Region	Walter Bucher
The Coal Resources of Kentucky	W. R. Jillson

These reports when completed will cover the most important fields of geological research in Kentucky, and will relieve the great call for works of general and State-wide application. Their publication will allow for, as soon as the several topographic base maps can be completed, more detailed considerations of separate quadrangle areas.

EXPENDITURES.

The Kentucky Geological Survey receives by way of appropriation from the State of Kentucky for all of its activities a total of $35,500.00, which is subdivided as follows:

General fund	$15,000.00
Base mapping (Topographic)	12,500.00
Printing	5,000.00
Salary of Director	3,000.00

This fund has been augmented by co-operative agreements as follows: Mapping fund of $12,500.00 has been increased by the same amount, $12,500.00, from the United States Geological Survey, with the result that $25,000.00 has been spent annually in this State. During the past biennial period $500.00 has been appropriated from the general fund of $15,000.00 for water resource work, which has been met with the same amount from the United States Geological Survey, thereby insuring the expenditure of $1,000.00 on water re-

source work in the State of Kentucky. The work on the Mississippian Series in Kentucky has also been a co-operative agreement, in which Mr. Chas. Butts, permanent employee of the United States Geological Survey, was engaged to do this work in this State, the United States Geological Survey and the Kentucky Geological Survey meeting his expenses in equal amounts.

The total expenditures of the Kentucky Geological Survey during this biennial period as given by the State Auditor are:

April 1, 1920 to July 1, 1920	$ 7,943.44
July 1, 1920, to July 1, 1921	35,497.46
Grand total from April 1, 1920, to July 1, 1921	$43,440.90

RECOMMENDATIONS TO GOVERNOR AND LEGISLATURE.

Investigations and discoveries of a mineralogical and economic nature which have been made by the Kentucky Geological Survey during the past biennial period have demonstrated conclusively that the State of Kentucky is literally a treasure-house for many of the crude mineral resource materials demanded by the complicated industries of the present day. The most of these materials are today either in point of first development, or unknown to the general public. The Kentucky Geological Survey, principally through its printed reports, is the only medium by which the general public may be informed concerning this unappraised and latent natural wealth of the State.

It is unfortunate that this State Department, which is logically the key to a greater and richer Kentucky, should be neglected, or given short consideration year after year, when its thoughtful encouragement and fostering with but slightly increased appropriations would result in such large and State-wide benefits. It has been estimated that for every dollar expended on geological survey investigations in States in the Appalachian Region, $1,000.00 is ultimately brought back into the wealth of the State in which the original investment is made. This statement is not extravagant, but is if anything,

conservative. The great turnover of the moneys in the mineral development of a country, in the purchase and repurchase of materials, labor, services, as well as the direct remuneration to the State Treasury from new corporations, land and production taxes, increased and new reality assessments, is stupendous.

It is estimated by the Director and State Geologist that the total mineral and natural resources of the State of Kentucky have been developed 18+%. While no definite determination of the amount of mineral development in Kentucky is possible, due to the present system of mineral rights assessment, Table No. IV, in Article X, of this volume is offered as an approximate guide or index. It is based on the personal observations and reconnaissances of the Director and State Geologist, and is in the nature of an appraisement.

It is a fact that this amount of development, when compared to that of the sister States of Kentucky, is pitifully small. Facts and figures prove that a larger mineral development in Kentucky has been delayed by the lack of adequate and comprehensive topographic base and geological maps of this State. The mineral resource development of Kentucky, or any other State, cannot be promoted or advanced rapidly without standard base maps and standard indexing geological reports. These the State of Kentucky has not provided for its citizens in the same measure as has its sister States, Virginia, West Virginia, Ohio, etc. The result is that these adjoining States have sprung ahead in their development, and Kentucky has lagged.

It is recommended that the Legislature of 1922 adopt some definite plans looking to the completion of the topographic base map of this State in the near future. This map is only 46.4% completed (Aug. 1, 1921), and at the rate the work is being done, it will not be finished within seventy-five years. The mapping of this State is fundamental to all highway improvement, drainage engineering, water resource engineering, mineral resource development, and many other broad regional projects. A Federal Bill looking to the completion of the topo-

graphic base map of the United States, Temple Bill No. 5230, is now in Congress, and will probably receive favorable action. Kentucky State appropriations for this important public work should be increased at least 100%, which would give then the relatively small sum of $25,000.00 to meet the same co-operative sum from the United States Geological Survey. Such action would insure the expenditure of $50,000.00 annually, and hasten the day when this State would be completely mapped, when this appropriation should cease.

The geological appropriation of $15,000.00 is not adequate to bring into this State geological and other specialists of high character and ability with which to carry on the investigations necessary to the exposition of Kentucky's mineral resources. The general fund should be increased from $15,000.00 to $20,000.00. At the last session of the legislature $5,000.00 was appropriated for printing, which under the present budget regulations will be extended to cover paper. It has been found that this amount is altogether too small to allow for the printing of bulletins and maps as required by the statute in sufficient quantity to supply the public demand. A number of important manuscripts and maps have been and are still held up indefinitely for lack of sufficient funds for engraving and printing. It is recommended that the present appropriation of $5,000.00 for printing be increased to $7,000.00. No recommendations are made concerning an increase in salary for the Director and State Geologist, the amount of which is now $3,000.00; but it is pointed out that in the future it will be difficult to secure a man sufficiently trained to administer this important public office in the way it should be for this small amount of money.

It is recommended finally that the governing statute be modified, so that the Director may place a nominal or approximate cost price on all maps and publications and sell same to those desiring them, as is done in other States, the money derived from such proposed sale of publications to be returned and added to the printing appropriation of the Survey, and be reused for printing and engraving purposes. This policy

would allow a saving, in that smaller editions of maps and reports could be issued, and a broader service, since enlarged funds would provide for more diversified publications.

AVAILABLE MAPS AND REPORTS.

The Kentucky Geological Survey has now ready for immediate distribution to any interested individual, corporation, company or institution requesting same, a large number of special reports and maps. These cover the general geology and the development of the many mineral resources of a large portion of the State. The early reports of the Kentucky Geological Survey are entirely exhausted, but those which can now be secured have been hereinunder listed in chronological sequence, by titles and authors. The required postal charge, and the number still available, is also indicated. The total number of reports now in stock covering the several indicated subjects is 23,245. A request for any of these publications to the Director of the Kentucky Geological Survey, when accompanied by the required amount of postage in stamps, will be promptly complied with, until the edition is exhausted. The list given is an essential duplicate of the one used in the official correspondence of the Survey.

LIST OF AVAILABLE MAPS AND REPORTS.

October 1, 1921.

INSTRUCTIONS FOR ORDERING: Single copies of any and all maps and reports listed hereunder will be mailed to any interested individual, corporation, company, or institution requesting same, providing the exact postal fee as indicated is forwarded with the request. Packages will not be sent express collect. This survey will not bill any applicant for required postal charges. Avoid delay and confusion by accompanying your letter of request with money order or stamps in the proper amount. Do not send checks.

GEOLOGIC REPORTS

SERIES VI.

(1920—Date.)

"W. R. Jillson Survey."

	Required Postal Charge	Copies in Stock
Vol. 1.—Glass Sands of Kentucky. C. H. Richardson, 1920	$0.20	441
Vol. 2.—Economic Papers on Kentucky Geology, W. R. Jillson, 1920	.20	212
Vol. 3.—Oil Field Stratigraphy of Kentucky. W. R. Jillson, 1921. In Press	.25	
Vol. 4—Geology of the Golconda Quadrangle. Stuart Weller. 1921. In Press	.25	
Vol. 5.—Geology and Coals of Webster County, L. C. Glenn, 1921. In Press	.25	
Vol. 6—Sixth Geological Survey. W. R. Jillson, 1921	.25	500
Total Copies Series VI		1,153

SERIES V.

(1918-20)

"Dept. of Geology and Forestry."

Bulletin No. 1.—Oil and Gas Resources of Kentucky, W. R. Jillson, 1919	.25	1,887
Bulletin No. 2.—Geology of Kentucky. A. M. Miller, 1919	.25	144
Bulletin No. 4—Contributions to Kentucky Geology. W. R. Jillson, 1920	.20	922
Total Copies Series V		2,953

SERIES IV.

(1912-13)

"J. B. Hoeing Survey."

Vol. 1, Pt. 1.—Oil and Gas Barite. Fluorspar and Lead —Water Power—Coals of the Big Sandy Valley, Geology of Tell City Quadrangle, Geology of Owensboro Quadrangle, Geology of Georgetown Quadrangle, Trenton Horizons, Chemistry of Trenton Rocks, Phosphate Deposits in Central Kentucky, Barite Deposits in Central Kentucky. 1913. Maps	.30	383

SERIES IV.—(*Continued*)
(1912-13)
"J. B. Hoeing Survey."

	Required Postal Charge	Copies in Stock
Vol. 1, Pt. 2.—Fire Clays of Northeast Kentucky, Technology of Kentucky Clays, Coals of the Upper Licking River, Coals of the North Fork of Kentucky River, Oolitic Limestones of Warren County, Kentucky Asphalt Rock, Soil Surveys, The Manufacture of Coke, Elevation in Kentucky, Astronomical Stations in Kentucky. 1913. Maps	.30	592
Vol. 3, Pt. 3.—Coals of the North Fork of Kentucky River in Perry and Parts of Breathitt and Knott Counties. Reprint. 1918. Maps.	.20	182
Vol. 4, Pt. 1.—Coals of Letcher County. 1916. Maps	.20	154
Vol. 4, Pt. 3.—Coals of Clay County. 1918	.20	180
Vol. 5, Pt. 1.—Coals of the Middle Fork of the Kentucky River in Leslie and Harlan Counties 1918	.15	185
Vol. 5, Pt. 2.—Coals and Structure of Magoffin County. 1918. Maps	.30	10
Phosphate Rocks in Central Kentucky. W. C. Phalen. 1918	.15	50
Total Copies Series IV		1,736

SERIES III.

(1904-1912)
"C. J. Norwood Survey."

	Postal Charge Required with Order	Copies in Stock
Bulletin No. 2.—Lead and Zinc Bearing Rocks of Central Kentucky. A. M. Miller. 1905	$0.05	66
Bulletin No. 3.—Coals, Clays, Mineral Waters, etc., of Ky. Robert Peter, 1905	.05	504
Bulletin No. 5.—Upper Ordovician Rocks of Kentucky and their Bryozoa. John M. Nickles. 1905	.05	455
Bulletin No. 6.—Kentucky Clays. James H. Gardner. 1905	.15	180

SERIES III.—(*Continued*)
(1904-1912)
"C. J. NORWOOD SURVEY."

	Required Postal Charge	Copies in Stock
Bulletin No. 7.—Silurian, Devonion and Irvine Formation of East Central Kentucky. A. F. Foerste. 1906	.10	297
Bulletin No. 10.—Coals of the Licking Valley. A. R. Crandell. 1910	.15	53
Bulletin No. 13.—The Upper Cumberland Coal Field. J. M. Hodge. 1912	.15	113
Bulletin No. 14.—Coals of the Pineville Gap Region. A. R. Crandall and G. M. Sullivan. 1912	.15	109
Bulletin No. 16.—The Waverlain Formations of East Central Kentucky. W. C. Morse and A. F. Foerste. 1912	.05	288
Bulletin No. 17.—Coals of the Tradewater Region. L. C. Glenn. 1912	.10	299
Bulletin No. 18.—Coals of the Quicksand Region. F. Julius Fohs. 1912	.15	340
Bulletin No. 19.—Coals of the Central City, Madisonville, Calhoun and Newburg Quadrangle. F. M. Hutchison. 1912	.20	340
Bulletin No. 20.—Coals of the Hartford Quadrangle. James H. Gardner. 1912	.10	380
Bulletin No. 21.—Value of Dix River as a Source of Water Power. A. F. Foerste. 1912...	.05	650
Report of Progress for the years 1908 and 1909. C. J. Norwood	.05	286
Report of Progress for the years 1910 and 1911. C. J. Norwood	.05	95
Total Copies Series III		4,455

SERIES II. (NEW)

(1873-1892)

"JOHN R. PROCTOR SURVEY."

(1880-1882)

Geology of Mason County (maps). W. M. Linney. 1885	.10	11
Kentucky Fossil Corals. W. S. Davis. 1885 (bound incomplete)	.50	55
Kentucky Fossil Shells. Nettleroth. 1887	.40	91

"N. S. Shaler Survey."
(1873-1880)

	Required Postal Charge	Copies in Stock
Vol. 1, Pt. 2.—Report on the Botany of Barren and Edmonson Counties. John Hussey	.10	24
Vol. 3, Pt. 8.—Report on Unfinished Work. N. S. Shaler. 1877	.10	23
Vol. 5, Pt. 5.—A General Account of the Geology of a Part of Ohio County. C. J. Norwood. 1880	.30	30
Vol. 5, Pt. 8.—Limonite Ores of Trigg, Lyon and Caldwell Counties. W. B. Caldwell, Jr. 1880	.10	75
Vol. A, Pt. 1.—Chemical Analyses (linen bound reprints) of 1884 and 1890: 1st, 1875; 2nd, 1877; 3rd, 1878. (Chemical Reports) Robert Peter	.20	6
Total Copies Series II		315

SERIES I. (OLD)
(1854-1860)
"David Dale Owen Survey."
All publications entirely exhausted in edition.

SERIES II, III, IV, V, VI.
(1854-1921.)
MAPS
(Note—The postal charge for each map, unless otherwise stated is 10 cents.)

	Postal Charge Required with Order	Copies in Stock
Geological map of Kentucky, showing Oil and Gas Pools and Pipe Lines, Eastern and Western Coal Fields, etc., by W. R. Jillson and L. M. Sellier. June, 1920	$0.50	650
Map Packet, 1919, contains the following: Oil and Gas Pool and Pipe Lines of Kentucky (small), Geology of Barren County, Geology of Allen County, Oil and Gas Map of Warren County, Structural Geology of Breathitt County; Structural Geology of Knott County, Kentucky-Appalachian Oil and Gas Fields.		

SERIES II, III, IV, V, VI.—(*Continued*)

(1854-1921)

MAPS.

	Required Postal Charge	Copies in Stock
Geologic Map of Kentucky (small)	.30	977
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II

THE CUMBERLAND FALLS, WHITLEY COUNTY, KENTUCKY, METEORITE.[1]

By George P. Merrill

Curator of Geology United States National Museum.

This stone which fell on the 9th of April, 1919, has been the subject of a note mainly descriptive of the fall,[2] by Prof. Arthur M. Miller, of Lexington, Kentucky, to whom the museum is indebted for his efforts in securing a considerable portion of the material.[3] The stone is of so unusual a type that it is worthy of more extensive notice than that given by Professor Miller, and fortunately the amount of the material secured is amply sufficient for the purpose.

On mere casual inspection there is little about the stone to suggest its ultra terrestrial nature. It is safe to say that had it not been seen to fall it would have been passed over even by one having a more or less intimate acquaintance with meteorites. On a broken surface it is of a light ash gray color, of a coarse texture, and might readily be mistaken for a terrestrial pegmatite in which the feldspar had undergone more or less whitening through weathering. Close examination reveals a pronounced brecciated structure produced by angular fragments of a chalky white mineral in pieces of all sizes up to 2 or more centimeters imbedded in a finer grey ground of apparently the same nature. Occasional inclosures of a dark gray-brown, almost black color, in one or two instances 3 to 5 cm. in diameter and angular in outline, exaggerate the pronounced brecciated structure which becomes so evident on a polished surface. Abundant flecks of a coal black, highly

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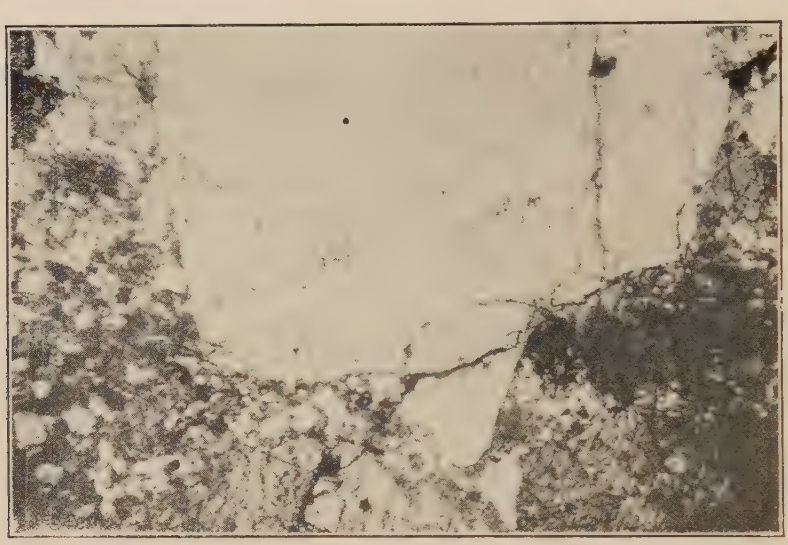
[1]Reprinted from vol. 57, 1920, U. S. National Museum.

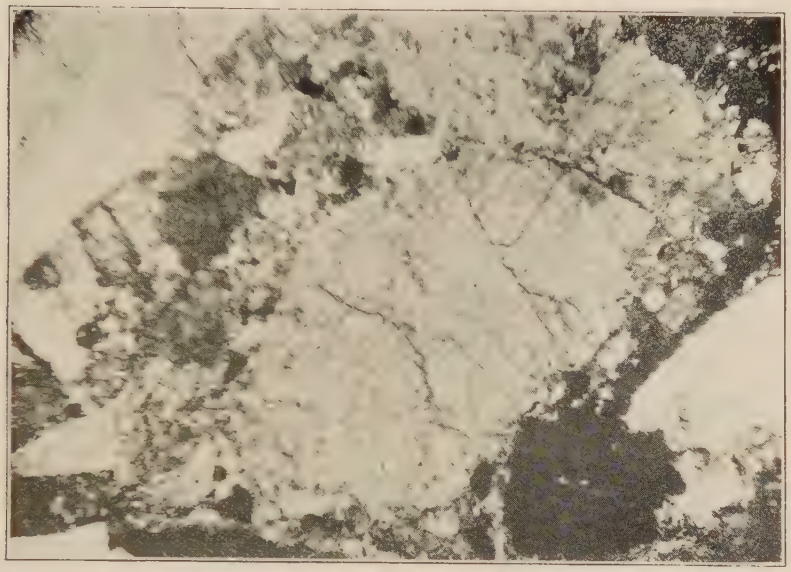
[2]Science, June 6, 1919; Also The Mineral Resources of Ky., vol. 1, ser. 5, No. 2, July 1919, pp. 110-114.

[3]Two complete individuals weighing respectively 567 and 23,478 grams and 13,476 grams of fragments. A 190-gram fragment was donated also by Mr. L. E. Bryan.



Microstructure, under low power, of the Cumberland Falls, Ky., Meteorite.

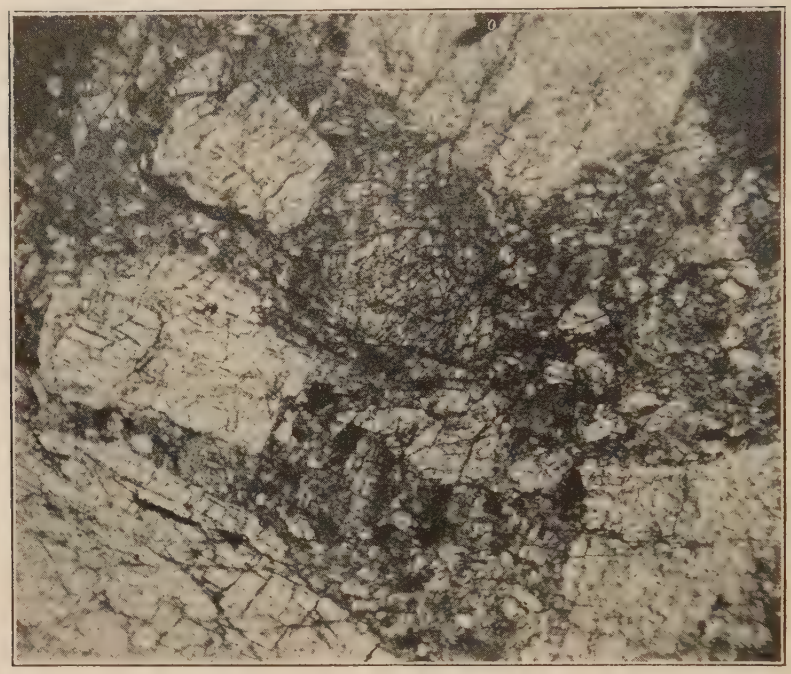
lustrous material are scattered irregularly through the ground, sometimes so abundant and of such small size as simply to render the rock dark gray in color, or again in shining blotches 10 to 15 mm. in diameter. Investigation shows these to be graphite. No iron or iron sulphide is noticeable on the broken surface and only abundant spots of newly formed iron rust suggest the presence of a ferrous chloride. The fusion crust or rind is inconspicuous of a yellowish to dirty yellowish-brown color, smooth and extremely thin—a mere skin coating. In several instances there was noted on freshly broken surfaces, small very thin areas of coal black or smoke-black glass. The cause of this or its relation to the crust is not readily apparent, but it is doubtless the very last fusion product of atmospheric resistance before reaching the earth. The usual pittings or thumb marks are present though the rock has become broken into so many pieces that these are not in all cases markedly evident. A local slickened movement is developed along the graphitic areas but which in no case observed extends throughout the mass. It would indicate



Microstructure, under low power, of the Cumberland Falls, Ky., Meteorite.

merely such a movement as would take place within a mass under compression, without the production of faults. On the polished surface scattered particles of metallic iron and iron sulphide are readily observed, but they are extremely irregular in their distribution, and much more abundant in the dark, nearly black enclosures referred to. An interesting feature is the peculiar weathered appearance of even a fresh fracture. Fragments broken through the impact of fall and gathered within a few days show dead, lusterless surfaces, as though exposed for many weeks or months. It is probable that this is due to the physical condition of the main constituents, noted later.

In the thin section the white, chalky mineral referred to is seen to make up the main mass of the rock, though in various conditions of fragmentation from almost perfect forms to mere dust. These are often so crushed, crumpled, and otherwise distorted as to give only undulatory extinctions, and with other optical properties badly obscured. More per-



Microstructure of the Cumberland Falls, Ky., meteorite illustrating the crushed and brecciated structure.

fect forms occur as broad plates with well-defined verticle cleavage lines giving parallel extinctions. Basal sections show imperfect, nearly rectangular prismatic cleavage and the emergence of an optic axis. These facts together with the refractive indices (1.658+) and the results of Mr. Shannon's analyses leave no question but that the mineral is enstatite. In many sections, however, the mineral shows in polarized light irregular, wavy, and interrupted bandings which extinguish alternately as the stage is revolved, in a manner at first suggestive of the polysynthetic twinning of monoclinic proxenes or feldspars. In these cases the broader more continuous bands give parallel extinctions and show in converged light the emergence of a bisetrix. The narrow, often indistinct and pinched out bands give inclined extinc-

MICROSCOPIC DETAIL OF METEORITE.

Dark enclosure shown in Pl II enlarged about 3 diameters. The light spots and streaks in the dark portion are metal.

tions running as high as 37°. No distinction in color or refractive indices is noticeable, but there is apparently no question but there is here an intergrowth of orthorhombic and monoclinic forms in the usual manner. If the analyses made by Mr. Shannon correctly represents this intergrown material (it was selected and analyzed before such an intergrowth was suspected) the proportional amount of the monoclinic form as indicated by the amount of alumina and lime (1.09 Al_2O_3 and 0.96 CaO) must be very small. The extreme narrowness of the bands giving the inclined extinction is, however, at least partially confirmatory of this.

The chalky appearance of the mineral is plainly due to its physical condition, an abnormal development of the cleavage, which incidentally causes it to crumble away under slight pressure and makes it susceptible of being ground to powder in an agate mortar as readily as so much calcite. Whether this condition is due to the shock which resolved the original mineral into fragments is uncertain, but it would seem most probable. The failure to become recompacted under subsequent pressure might well be ascribed to a lack of moisture, pressure and dry heat alone naturally being less conducive to metamorphism.

In addition to the above, certain of the slides show intergrown with the enstatites in the form of small oval and irregular areas a brilliant polarizing mineral with the sharply developed platy structure characteristic of diallage. The mineral is also nearly colorless, with a very faint green tinge, and gives extinction angles measured against the edges of the plates; i. e. on clino-pinacoidal sections as high as 27°. The proportional amount of the diallage is quite variable, some slides showing only an occasional rounded granule and others several of the intergrowths mentioned.

Scattered irregularly throughout the mass of the rock are the scale-like segregations of graphite, above noted, sometimes several millimeters in diameter, in connection with which a differential movement has given rise to small areas with slickensided surfaces. In the finer portions, the graphite is

so evenly and finely diffused as to impart a dark gray color. Metallic particles are quite inconspicuous excepting on a polished surface, as are also those of iron sulphide. The relatively greater abundance of the metal and sulphide in the dark inclosures, above noted, is very evident on the polished surface. No calcium phosphate, maskelynite, oldhamite, osbornite, or other accessory minerals can be detected, although microchemical tests give rise to the usual globular ammonium-phospho-molybdate forms.

FRAGMENT OF CUMBERLAND FALLS METEORITE.
Cut and polished fragment of Comberland Falls, Ky., meteorite showing brecciated structure and dark enclosures.

A close study of the dark inclusions developed some i
esting and unexpected conditions. Examination with a
lens of the polished surface of one of the larger in
shown in plates 2 and 5 at once suggests a chondrit
ture, a suggestion fully borne out by a study of th
in thin section, which shows a dark, obscure,
ground containing numerous illy defined compre
torted radiating, barred, and nearly holocrystalli

of olivine and enstatite, mostly so obscured by a black impregnation that their true mineral nature is scarce recognizable. In these respects the structure so closely resembles that of the McKinney and Travis County, Texas, stones and others of Meuniers tadjerite group as to suggest a similar origin; that is, as developed from a normal chondrite (aumalite) through a process of heating. It is further to be noted that the dark portions are much richer in metal and, judging from the formation of abundant hydroxide of iron on a freshly cut or broken surface, richer also in ferrous chloride. These facts are borne out by the analyses noted later. The manner in which the metal occurs is interesting and peculiar, leaving no question as to its secondary origin and the foreign nature of the inclusion as well. One of these occurrences is shown enlarged some three diameters in plate 5, the metal in fine threads cutting across the surface in a manner strongly suggesting the figures sometimes given to show the play of lightning during a heavy electrical storm. Aside from these forms the metal at times completely surrounds a chondrule and even penetrates into it in the form of fine threads. The appearance is in entire accord with the idea of its late introduction after the crystallization.

It is evident at once that we have here a meteoric breccia composed of fragments of two quite dissimilar stones. This is sufficiently apparent from both megascopic and microscopic examination. The careful work of Mr. Shannon, in the analyses quoted below, is fully confirmatory.

Chemical Analyses by Mr. E. V. Shannon.

Before the intergrown nature of the pyroxenic constituents ere suspected the clean chalky-white portion was carefully pled, crushed, and separated from possible impurities by ercuriciodide gravity solution. The results of an analy- he powder thus obtained are given in column I below. nns II and III are given for purpose of comparison reported analyses of enstatite from the meteorites ille, South Carolina, and Hvittis, Finland. The with the enstatite of Hvittis. it will be noted, is lose.

Detail of Microscopic Structure of Cumberland Falls Meteorite.

Analyses of enstatite.

	Cumberland Falls.	Bishopville.	Hvittis.
	I	II	III
SiO_2	59.53	59.97	59.05
Al_2O_3	1.09	.....	1.09
MgO	37.17	39.34	37.10
FeO	.98	.40	.90
CaO	.96	.....	.98
(Ba, Sr)O	None.	Na_2O	.68
NiO	None.	K_2O.	.47
Loss on ign	.33	.....	.....
Total	100.06	99.71	100.07

Bulk Analyses of the Light (Major) Portion of the Meteorite.

A 70-gram fragment which, so far as could be judged, was representative of the gray brecciated portion of the stone, was selected and, through the courtesy of Dr. George Steiger, ground at the laboratory of the survey. This yielded as in column I below. Unfortunately Mr. Shannon was not present during the process of grinding and it is possible that a larger portion of small particles of the dark stone were incorporated in the mass than was surmised from the appearance of the fragment. The probability of this, which was not at first realized, is suggested by the slight excess of magnesia (MgO) and ferrous oxide (FeO) in the bulk analysis over that in the enstatite given above. In columns II, III, and IV are given for comparison previously published analyses of the Busti, Bishopville, and Shalka stones. It will be noticed that so far as the magnesium is concerned the Cumberland Falls stone agrees very closely with that of the first-named, although a trifle higher in silica.

	I	II	III	IV
Silica (SiO_2)	55.172	52.73	57.034	52.51
Alumina (Al_2O_3)	.382		1.706	.66
Chromic oxide (Cr_2O_3)	.062			1.25
Phosphoric oxide (P_2O_5)	Trace.			Trace.
Iron (Fe)	.888		.181	.25
Manganese (Mn)	.005			
Nickel (Ni)	.059		.039	
Cobalt (Co)	.004			
Copper (Cu)	.003			
Chromium (Cr)	Trace.			
Nickel oxide (NiO)	.123	.78	.538	
Cobalt oxide (CoO)	Trace.		Trace.	
Ferrous oxide (FeO)	2.916	4.28	1.265	16.81
Lime (CaO)	1.586	1.18	2.016	.89
Magnesia (MgO)	38.734	36.22	33.506	28.35
Manganous oxide (MnO)	.112	.01	.189	
Soda (Na_2O)	.157		1.027	.22
Potash (K_2O)	.150		.089	
Water (H_2O)	.167	Ign.	1.195	
Sulphur (S)	.784		.297	.14
Phosphorous (P)	.034			
Chlorine (Cl)	.028	[1] 2.35		
Carbon (C)	.164	[2] 92		
	101.530	99.47	100.023	100.08
Less O for (Cl, S, P)	.569		.147	
	100.961		99.876	

[1] $Na_2SO_4CaSO_4CaCl_2$. [2] Ign.

The results given in column I seemingly bear out the microscopic determinations, and, in connection with the analysis of the white pyroxenic constituents given and warrant the conclusions drawn as to the mineral composition of the stone. It is to be noted, however, that qualitative tests show an unusually large proportion of silicate matter soluble in acid, and suggest the need of further chemical work. This must, however, be deferred for the present.

The 0.888 per cent of metal yielded:

Iron (Fe)	92.596
Nickel (Ni)	6.152
Cobalt (Co)	.417
Manganese (Mn)	.522
Copper (Cu)	.313
Chromium (Cr)	Trace.
	100.00.

Bulk analysis of the dark chondritic inclosure, yielded:

Silica (SiO_2)	41.683
Alumina (Al_2O_3)	1.537
Chromic oxide (Cr_2O_3)	.591
Ferrous oxide (FeO)	9.399
Nickel oxide (NiO)	.211
Cobalt oxide (CoO)	trace
Phosphoric oxide (P_2O_5)	trace
Lime (CaO)	4.059
Magnesia (MgO)	27.848
Iron (FE)	12.108
Nickel (Ni)	.747
Cobalt (Co)	.078
Copper (Cu)	.001
Chromium (Cr)	trace
Manganese (Mn)	.088
Potash (K_2O)	trace
Soda (Na_2O)	trace
Chlorine (Cl)	.045
Sulphur (S)	2.464
Phosphorous (P)	.014
Carbon (C)	.449
Ignition (H_2O)	.210
	102.011
Less O for (Cl, S, P)	1.448
	100.563

In comparison with the other chondritic stones this offers no unusual features.

Treated with dilute hydrochloric acid (sp. gr. 1.06) and sodium carbonate solution in the customary manner the sili-

cate portion free from metal and metallic sulphide yielded 22.582 per cent of soluble matter of the following composition:

Silica (SiO_2)	38.239
Alumina (Al_2O_3)	trace
Ferrous oxide (FeO)	6.566
Nickel oxide (NiO)	.043
Manganous oxide (MnO)	.709
Cobalt oxide (CoO)	trace
Lime (CaO)	5.246
Magnesia (MgO)	49.197
	100.000

The 56.58 per cent insoluble silicates yielded:

Silica (SiO_2)	58.341
Alumina (Al_2O_3)	2.705
Ferrous oxide (FeO)	3.528
Nickel oxide (NiO)	.295
Cobalt oxide (CoO)	trace
Manganous oxide (MnO)	.562
Lime (CaO)	5.073
Magnesia (MgO)	29.496
	100.000

This bears out the somewhat unsatisfactory determination of the prevailing orthorhombic nature of the pyroxenic constituent, but the high (5.246) per cent of lime (CaO) is difficult to account for.

The 13.022 per cent metallic portion yielded:

Iron (Fe)	92.982
Nickel (Ni)	5.735
Cobalt (Co)	.599
Manganese (Mn)	.676
Copper (Cu)	.008
Chromium (Cr)	trace
	100.000

The mineralogical composition of the dark inclusion as calculated from the foregoing is as below:

Metal	13.022
Troilite	6.760
Lawrenscite	.080
Chromite	.869
Soluble silicates mainly olivine	22.582
Insoluble silicates mainly pyroxenes	56.580
Carbon, mainly amorphous	.449
Calcium phosphate	trace
Water, hygroscopic	.210
	100.472

The most striking features of the stone, aside from its coarse brecciated structure, are the marked evidences of compression manifested in the numerous small slickensided surfaces and the crushed and optically distorted condition of the pyroxenes, as shown both in the hand specimens and in thin sections. It is to be noted that while the original shattering which resulted in the production of the fragments may have been due to impact or explosive action the mass has since been subjected to pressure under a heavy load whereby the particles have been further crushed and distorted and once more welded into a firm, rock-like mass. These are characteristics of deep seated terrestrial rocks that have been subjected to dynamic metamorphism.

The question naturally arises, is not the distortion so conspicuous in so much of the enstatite due to the crushing which resulted in the disintegration of the original meteorite rather than to any subsequent pressure? This question, I think, may be answered in the negative, though not with absolute certainty. The study of the sections shows that the line of contact between the light stone and the dark inclosures, while apparently sharp, is, as shown in the thin section, quite irregular, as a rule, particles from the one projecting into the other, though the superior hardness and toughness of the dark stone make this a less conspicuous feature than it might otherwise have been. Portions of the enstatite, are, however, jammed

A METEORITIC INDIVIDUAL.
This complete individual of Cumberland Falls meteorite weighed 2,347 grams.

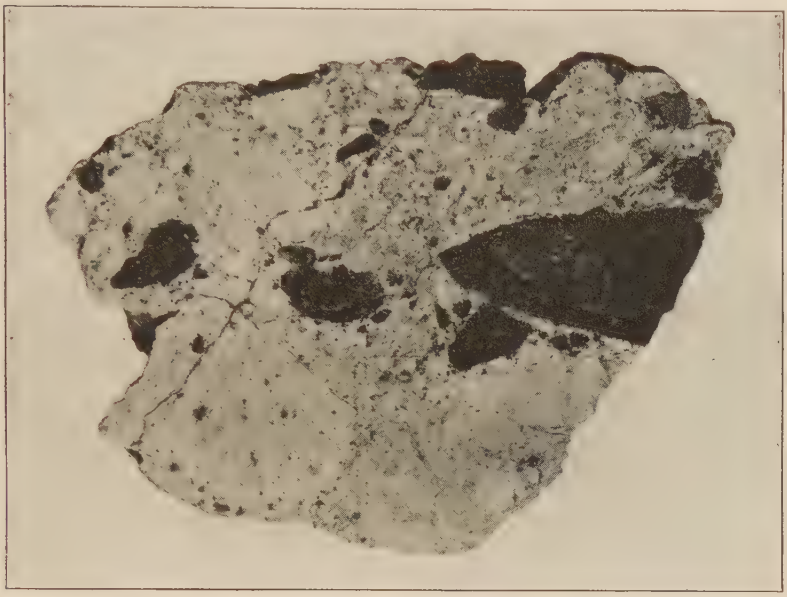
into the chondritic stone and particles of the chondritic stone into the enstatite as shown in the accompanying figure. In one instance where a section has been so cut as to cause one of these interpenetrations to appear as an inclusion in the chondritic stone, a minute fault can be traced cutting through both pieces and making itself conspicuous by a slight off-set. Apparently, the admixture of the two kinds of fragments took place prior to the evident compression and both stones were involved. The numerous slickensided areas sometimes of a few square centimeters dimensions further testify to the compression and condensation in mass which the stone has undergone.

These structural characteristics are, as it seems to me, to be accounted for only on the supposition that the detrital matter composed of materials derived from the disintegration of previously consolidated rock masses of at least two distinct types, accumulated on the surface as in the case of an ordinary terrestrial volcanic breccia. Subsequently the beds were deeply buried and through crustal movements the material compressed into its present condition. This supposition carries with it the supposition that the meteorite is but a spawl from a very much larger mass, one of such size, indeed, as to have been subject to such crustal movements as are incidental to mountain making and which find their terrestrial counterpart in regions of maximum disturbance, as in the steep synclinal folds of our southern Appalachians. How large such a mass must be it is impossible to say, but that it must have been of planetary dimensions would seemingly be a safe assumption. In fact, that the fragments are direct evidence of the destruction of some preexisting planet seems a legitimate conclusion.

Incidentally, it may not be out of place to call attention to the fact that this adds one more to the most acidic type of magnesia-rich stones which have been seen to fall and all of which have come to us in a period of a little more than 100 years.[1]

It must be evident from what has gone before that this stone has no exact counterpart among known meteorites and finds no exact place in the prevailing scheme of classification. Disregarding the inclosures of the chondritic stone it differs from the Bustites which chemically it closely resembles in carrying no appreciable amount of oldhamite, plagioclase, or osbornite and in its pronounced brecciated structure. From the chladnites it likewise differs in structure and its relatively high magnesia content. Nevertheless, it would seem more nearly related to these groups than others, though on the polished surface it suggests at first a remote similarity to the St. Michel stone described by Borgström and relegated by him

[1]See Merrill, G. P., The percentage Number of Meteorite Falls and Finds considered with Reference to their Varying Basicity. Proc. Nat. Acad. Sci., vol. 5, pp. 37-39, Feb. 1919.



A STUDY IN METEORITIC STRUCTURE.
Cut and polished fragment of Cumberland Falls, Ky., meteorite showing brecciated structure and dark enclosures.

to the rhodites. The Cumberland Falls stone, however, carries no chondrules. It is a breccia, as already noted, and its mineral composition, aside from the chondritic inclusion, is limited almost wholly to the enstatite with an intergrown monoclinic forms, sporadic diallage, and small quantities of metal, metallic sulphide, and graphite. In an attempt to make a position for it in the system of classification generally adopted,[1] I will suggest the name of *Whitleyite*, (Wht.), and define it as a coarse white to gray breccia composed chiefly of enstatite with minor quantities of diallage, metal, metallic sulphide, and graphite, and with sporadic inclosures of a black chondritic stone. The term Cumberlandite might have been selected, but that this name has been preempted by Wadsworth[2] for the terrestrial peridotite of Cumberland, Rhode Island. Whitley is the name of the county in which Cumberland Falls occurs.

[1]See Wulfing, pp. 446-160.
[2]Lithological Studies, p. 8.

III

GEOLOGY AND COALS OF THE MIDDLE FORK OF THE KENTUCKY RIVER NEAR BUCKHORN IN PERRY AND BREATHITT COUNTIES

By Willard Rouse Jillson,
Director and State Geologist.

LOCATION AND FIELD WORK.

The area herein to be discussed is located in the heart of the Eastern Kentucky coal field. It lies generally from ten to fifteen miles slightly to the southwest of Jackson, the seat of Breathitt County, and about fifteen to twenty miles northwest of Hazard, the seat of Perry County. Situated on the waters of the Middle Fork of the Kentucky River and some of its tributaries, the Buckhorn section is removed from the nearest line of transportation, the L. & N. Railroad, on the North Fork of the Kentucky River, from two to ten miles. In an airline, the little mountain town of Buckhorn, which is located in the center of this area, is about 75 miles southeast of Lexington, Kentucky, but by railroad, wagon road, or trail, it is over 100 miles. The Buckhorn section is slightly south of the latitude 37° 30′, and nearly bisected by longitude of 83° 30′.

The data presented herewith is based upon the writer's personal investigations in the field from February 3rd to February 10th, inclusive, 1921; and April 20th to April 23rd, inclusive, 1921. Examinations were made along a route from Altro on the North Fork up Bush Creek to and down the Left Fork of Gays Creek to the Middle Fork of the Kentucky River, and thence to Buckhorn. Squabble Creek in the vicinity of Buck-

OUTLINE MAP OF THE BUCKHORN REGION.
It will be readily seen that although railroad transportation skirts this region on the right on the North Fork, the Buckhorn section on the Middle Fork of the Kentucky River is actually isolated.

horn was then covered; thence up Otter Creek to its head; thence down the Middle Fork of the Kentucky River and its shorter tributaries, Buck Branch and Cam Johnson Branch, and up Johnson's Fork and Riley's Fork of Long's Creek. Thence the route lead down the Middle Fork of the Kentucky River, and up Bowling's Creek to its head, and back down Bush Creek to Altro Station. Another later route of examination started at Chavies Station on the North Fork of the Kentucky River, up Eversole Creek and down the Right Fork of Gays Creek to Otter Creek and Buckhorn, and thence back over Gays Creek to Chavies. No examinations were made on Turners Creek and Lick Creek, due to the lack of adequate openings on these streams. The photographs included within this report were made by the writer in the field, under the certain handicaps of rainy and foggy, though mild, weather.

ALTRO, BREATHITT COUNTY, KY.

The North Fork of the Kentucky River in the middle background has developed a series of cliffs in the Pottsville on the outside of a local meander. The Louisville and Nashville Railroad right of way is in the foreground.

OUTLINE MAP OF BUCKHORN REGION.
Buckhorn is located in the western central portion of the map. The topography is quite characteristic of the Cumberland Plateau in Kentucky.

Practically all of the openings examined were wet, that is, dammed up by slips or natural dip, and contained amounts of water ranging in depths from 6 inches to 4½ feet. A considerable amount of time, and not a little labor, was required to drain these entries, in order to allow for measurement, channel sampling, and photographing. The geologic coal section for this report is given as at Buckhorn, because of the larger number of openings in that vicinity than at any other one place, and because of its semi-central position in the area reported upon. All of the coals in the section, however, were not opened and hence not examined at Buckhorn. Many were found in the adjacent territory and brought into this section

PANORAMA OF BUCKHORN, KY.

Witherspoon (Presbyterian) College and Campus are seen in the foreground. Native residences and stores are strung out to the right and left on the branches of Squabble Creek.

and correlated by means of barometric elevations and special characteristics.

In the section covered, all of the known openings were inspected, including those of commercially operated mines of the Eversole and Bush Creek sections on the North Fork of the Kentucky River, as well as the sporadically operated domestic mines on the Middle Fork of the Kentucky River. Great courtesy was extended to the writer by many individuals within this area, who spared no effort to give complete information as to the location of the domestic openings. Officials of the Johnson-Hogge Coal Co., the largest individual operator on Eversole Creek, were especially courteous in allowing a special inspection of their several mines, and assisting in the sampling of the coals therein operated.

GEOLOGY.

Topography, Stratigraphy and Coals.

The highest elevation within the area is slightly over 1,600 feet A. T. This altitude is found on the divide between the Middle Fork and South Fork of the Kentucky River. The minimum

LONG'S CREEK AFTER A HARD RAIN.

The forest denuded hillsides of this region do not retain the precipitation long. Following a rain of a few hours' duration the creeks rise rapidly and the roads are flooded.

elevation is found near the mouth of Bowling's Creek in Breathitt county, and is 700 feet A. T. at low water. At Buckhorn, which is located on Squabble Creek at its juncture with the Middle Fork of the Kentucky River, the drainage floor is 730 feet at low water.

The topography of the region is a unit with that of the interior of the Eastern Kentucky coal field, consisting of an adjusted intricate system of typically dendritic drainage deeply incised into the Cumberland plateau. The ridges, which are uniformly sharp and timbered in second growth and virgin culls, give a widespread and outstanding accordance of summit levels. The valleys are narrow, meandering and generally under cultivation. The roads—better described as trails find-

THE MOUTH OF OTTER CREEK.
One stands at the elevation of the Hazard coal and the view is up the Middle Fork of the Kentucky River. Characteristic Pottsville topography.

ing their way in and along the creeks—are either uniformly bad or impassable. The inhabitants, the direct descendants of the original sturdy pioneers, though living generally in log homes, with somewhat primitive surroundings, have preserved for the interested coal prospector or occasional traveler that rare, abundant hospitality which has long been characteristic of the Kentucky mountaineer and his home land.

A COMFORTABLE MOUNTAIN HOME.
This residence is a double two story, weatherboarded, log cabin, and is typical of the better old-time homes of this hill region. It is owned by F. J. Johnson, and is located on the Cam Johnson Branch of the Middle Fork of the Kentucky River.

The rocks exposed at the surface of the area under discussion are those of the Middle and Lower Pottsville formations, the basal divisions of the Pennsylvanian System. A considerable thickness of these rocks including the Pottsville Conglomerate is to be found below drainage levels by well drilling or coreing. Above drainage, and forming the subject matter of this report, there is a maximum thickness of about 900 feet of alternating sandstones, shales and coals.

In the 900 feet of exposed strata there were found and definitely correlated in the field eleven coals. This enumeration classifies the Fire Clay or No. 4 coal and the Fire Clay Rider coal as separate coals. The enumeration begins at the Whitesburg or No. 3 coal, at 750 to 770 feet A. T., and goes up through Hindman or No. 9 coal at elevations ranging between 1,385 and 1,400 feet. The sequence of coals in ascending order as found follows: Whitesburg, or No. 3 coal; Stray coal B.; Stray coal C.; Fire Clay, or No. 4 coal; Fire Clay Rider Coal; Hamlin

coal; Haddix, or No. 5 coal; Hazard, or No. 6 coal; Flag, or No. 7 coal; Francis, or No. 8 coal; Hindman, or No. 9 coal.

BOWLING CREEK, BREATHITT COUNTY, KY.

The view is up the creek on the farm of Richard Combs. Note the road is in and out of the creek, which is foot bridged high enough to allow wagons to pass beneath. Note rapid erosion on barren hillside at the right.

A tabular presentation of these several coals is given below, wherein fuller information concerning their locations, thicknesses and relative positions in the geologic section may be secured:

SUMMARY OF COAL THICKNESSES.

(Partings are not included.)

Elev. Coal	Name of Coal	No. of Exam.	Location and Measurement
1385	Hindman	(34)	Gays Creek, 34 in. coal.
1350	Francis	(37)	Gays Creek, unopened, unmeasured.
1315	Flag	(38)	Gays Creek, unopened, unmeasured.
		(20)	Groundhog, Long's Creek, 57 in. coal.
		(36)	Eversole Ck., 35 in. coal.
		(39)	Gays Creek, fallen in. Rept. 40 in.
1250	Hazard	(1)	Middle Fork, 66 in. coal.
		(6)	Otter Creek, 50 in. coal.
		(35)	Eversole Creek, 24 in. coal.
1150	Haddix	(19)	Johnson's Fork, Long's Ck., 34 in. coal.
		(18)	Johnson's Fork, Long Ck., 27 and 21 in. coal.
1090	Hamlin	(7)	Otter Creek, 16 in. coal.
		(3)	Squabble Ck., 38 in. coal, solid.
		(26)	Eversole Ck., 29 in. coal.
		(27)	Eversole Ck., 40 in. coal.
930–970	Fireclay Rider	(30)	Gays Ck., 24 in. coal.
		(31)	Gays Ck., 33 in. coal.
		(16)	Cam Johnson Branch, 45 in. coal.
		(22)	Bowling Creek, 29 in. coal.
		(28)	Eversole Creek, 53 in. coal.
		(29)	Eversole Creek, 92 in. coal.
925–960	Fireclay	(30)	Gays Creek, 43 in. coal.
		(33)	Gays Creek, 39 in. coal.
		(15)	Buck Branch, 40 in. coal.
		(40)	Gays Creek, 18 in. coal.
		(2)	Squabble Creek, 35 in. coal.
750–770	Whitesburg	(10)	Squabble Creek, 24 in. coal, solid.
		(14)	Buck Branch, 20 in. coal.
		(17)	Riley's Fork, Long's Ck., 28 in. coal.
725–790 and up	Middle Fork Drainage Level		
680–690	Sub "A"		Variously reported, unmeasured.

STANDARD CORRELATION OF THE COALS OF THE BUCKHORN REGION IN PERRY AND BREATHITT COUNTIES, KY.

Elev. Coal	Hazard Field Nomenclature	Hazard Field Coal Number	Exam. No. This Rept.	Creek Location
1385	Hindman	No. 9	No. 34	Gays
1350	Francis	No. 8	No. 37	Gays
1315	Flag	No. 7	No. 38	Gays
1250	Hazard	No. 6	No. 1, 6, 20, 36, 39	Middle Fork, Gays, Eversole, Otter, Long's.
1150	Haddix	No. 5	No. 19, 35	Eversole, Long's.
1090	Hamlin	.....	No. 7, 18, 21	Otter, Long's Bowling.
930–970	Fireclay Rider	.....	Nos. 3, 16, 22, 23, 24, 25, 26, 27, 30, 31	Bowling, Bush, Squabble, Cam Johnson, Gays, and Eversole.
925–960	Fireclay	No. 4	Nos. 11, 15, 28, 29, 30, 33	Gays, Squabble, Eversole, Buck Br.
870	Stray C.		Nos. 5, 8	Otter.
800	Stray B.		No. 32	Gays.
750–770	Whitesburg	No. 3	Nos. 2, 4, 9, 10, 13, 14, 17, 40	Squabble, Otter, Gays, Middle Fk., Ky. River, Long's.
725–790 and up. Middle fork of the Kentucky River Drainage Level.				
680–690	Sub "A" Coal		Not listed.	

Besides the coals named above, frequent reference was made by natives in this area to "a thick solid coal underlying the river in low water about 30 feet." This coal was never seen by the writer, due to the fact that the Kentucky River and its tributaries were high at the time of the field work, and no shaft was open to it. There can be but little doubt, however, that some coal is existent at this point, though what

its measurements and partings might show under examination cannot be suggested here. It is probably not, however, a solid coal if it is over 3 or 3½ feet in thickness. In this report this lower than river drainage coal is called the "Sub A" coal. It underlies the Whitesburg coal. Whether or not it is to be correlated with the Amburgy or a lower coal is an open question.

Structural Features.

The major structure of the Buckhorn-Crockettsville area of Middle Fork of the Kentucky River is that of a great syncline. It is in fact the Eastern Kentucky geo-syncline, the bottom of the trough between the Pine Mountain uplift on the southeast, and the Lexington Dome of the Cincinnati Arch on the northwest. The lowest points in the stratigraphic sequence

CROCKETTSVILLE, BREATHITT COUNTY, KY.

This view is at the forks of Long's Creek. The store at the left was formerly owned by Ed Callahan who was shot from ambush there in the Hargis-Cockrill feud. The topography is characteristic of the Pottsville series.

of the rocks of this region are found near Crockettsville in a basin syncline which parallels the Middle Fork of the Kentucky River, and is located astride the Perry-Breathitt County line.

The Fire Clay coal in this immediate vicinity is contoured as low as 860 feet A. T., and may be found in one or two localities as low as 850 feet A. T. The highest structural point within this area is found on the Owsley-Breathitt line, where the Fire Clay coal is contoured at 1,030 feet, or from 100 to 120 feet higher than it is on the Middle Fork. Going to the east, the strata rise into the divide between the Middle and North Forks of the Kentucky River, beneath which there is located a low, elongated dome or up-folding on the rock series. The major axis of the structure, though not a straight line, is in a generally north and south direction. The Fire Clay coal on the top of this anticline is contoured at 910 feet, a rise of 50 feet from the vicinity of Crockettsville. From the top of the watershed between these rivers the strata again slope to the east, where they again find synclinal positions on the North Fork of the Kentucky River. The Fire Clay coal at the mouth of Strong Branch is contoured at 860 feet A. T., and at the mouth of Wolf Creek 870 feet A. T.

DETAILED EXAMINATIONS OF COALS.

Examination No. 1.

Property: John Gross.

Location: Just below mouth of Otter Creek on Middle Fork of Kentucky River, Perry County, Ky.

Elevation: Coal, 1,220 feet A. T.; top of ridge, 1,375 feet A. T.

Description: Hazard coal. Old domestic mine, high on hill, adequately timbered, and in excellent condition inside. Main entry badly fallen in, impounding about 4½ feet of water. Required entire day to open, drain, measure and sample. A very commercial seam, but small acreage at this point. Acreage would be much larger back from the river or the creeks. Sampled. See analysis.

Coal Section: Gray slate roof.
15 in. coal.
12 in. gray slate.
51 in. coal (solid).
Gray sandstone bottom.

HAZARD COAL AT THE MOUTH OF OTTER CREEK.
This coal is high in the hill on the farm of John Gross and measures 50 inches exclusive of the parting.

Examination No. 2.

Property: Jim Sandlin.

Location: At Buckhorn in waters of branch of Squabble Creek flowing from the northeast below Reynolds Bros.' store, Perry County, Ky.

Elevation: Coal, 750 feet A. T. (drainage level).

Description: Whitesburg coal. Considerably used (3) domestic openings close together, adequately timbered, but shallow, badly filled with impounded water from the branch. Not a commercial seam. Very large acreage; operated.

Coal Section: Gray slate roof.

16 in. coal.

½ in. slate parting.

19 in. coal.

Gray slate bottom.

Examination No. 3.

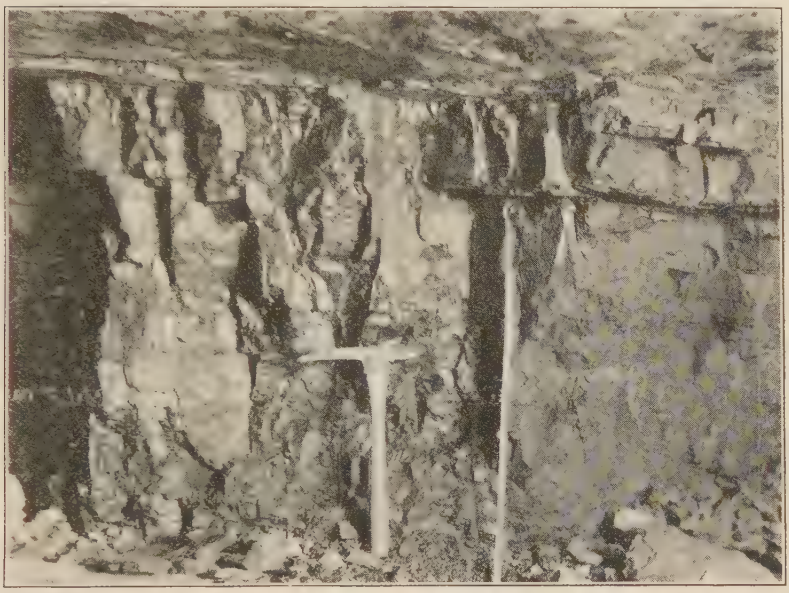
Property: Floyd Gross.

Location: At Buckhorn, half-way up hill on left side of Squabble Creek, Perry County, Ky.

Elevation: Coal, 1,000 feet A. T.; ridge, 1,250 feet A. T.

Description: Fireclay Rider coal. Operating mine used by Witherspoon College. Adequately timbered, dry. Main entry driven about 150-200 feet. Measured 38 in. solid coal 20 feet inside main entry, and reported 40 in. at face. A commercial seam. Sampled. See analysis.

Coal Section: Gray slate roof.
38 in. coal (solid).
Gray slate bottom.



THE FIRE CLAY RIDER—38 INCHES SOLID COAL.

This view is in the Witherspoon College mine on the Floyd Gross farm on Squabble Creek.

Examination No. 4.

Property: John Gross.

Location: On right side of Middle Fork of Kentucky River at right of county road and level with same, ½ mile above mouth of Squabble Creek, Perry County, Ky.

Elevation: Coal, 790 feet A. T.

Description: Whitesburg coal. Natural—unmined—outcrop badly weathered and soft. Not a commercial seam here.

Coal Section: 30 feet gray sandstone roof.
21 in. coal (would be more if faced to solid).
Shale bottom.

Examination No. 5.

Property: Lewis Strong.

Location: On left side of Otter Creek, 1½ miles above mouth, Perry County, Ky.

Elevation: Coal, 900 feet A. T.

A NEW OPENING OF THE HAZARD COAL.
This prospecting was done on the Levi Strong farm on the head of Otter Creek at an altitude of 1,230 feet.

Description: Stray coal. Old domestic opening only partly completed. This is the same coal as that underlying the black shale in the creek farther up and near the school house. Commercially unimportant.

Coal Section: Sandstone roof.
19 in. coal (solid).
6 feet slate (gray to black).
14 in. coal (solid).
Shale bottom.

Examination No. 6.

Property: Levi Strong.

Location: On left side of right fork of Otter Creek, 2½ miles above mouth of creek, Perry County, Ky.

Elevation: Coal, 1,230 feet A. T.

Description: Hazard coal. New opening, only partly completed, half-way up hill, not faced to the solid. Coal soft and rotten. Would be much thicker, especially above parting, if measured on the solid face. A very important commercial coal. Fairly large acreage.

Coal Section: Slate roof.
38 in. coal (solid).
4 in. gray slate.
12 in. coal.
Sandstone bottom.

Examination No. 7.

Property: Levi Strong.

Location: On left side of right fork of Otter Creek, 2½ miles above mouth of creek, Perry County, Ky.

Elevation: Coal, 1,090 feet A. T.

Description: Hamlin coal. New opening only partly completed, one-third distance up hill. Not faced to solid. Coal soft and rotten. Whole sequence probably not shown. The coals would be somewhat thicker if measured on solid face. A probably unimportant coal in this immediate locality, but undoubtedly important elsewhere. Large acreage here.

Coal Section: Slate roof.
18 in. bone and slate.
12 in. coal.
6 in. slate.
4 in. bone and coal.
Yellow and gray clay bottom.

Examination No. 8.

Property: Several owners.

Location: In Otter Creek just below the forks, Perry County, Ky.

Elevation: Coal, 880 feet A. T.

Description: "Stray" coal. Old domestic stripping operations in the creek bed. Black slate is lifted and the coal removed. Commercially unimportant.

Coal Section: 24–36 in. black fissile slate cover.
12–14 in. coal.
10 in. shale, yellow.

Examination No. 9.

Property: Edward Hogg.

Location: On the right of Otter Creek, three-fourths mile above mouth, Perry County, Ky.

Elevation: Coal, 790 feet A. T.

Description: Whitesburg coal. Old domestic opening fifteen feet above creek bed, under 30 feet massive sandstone. Commercially unimportant.

Coal Section: 30 feet sandstone roof.
18 in. coal.
Gray shale bottom.

Examination No. 10.

Property: Witherspoon College farm.

Location: Buckhorn, Ky. Under sandstone cliff near saw mill on Squabble Creek.

Elevation: Coal, 775 feet A. T.

Description: Whitesburg coal. Natural outcrop under very thick and massive sandstone. This coal not commercial at this out crop.

Coal Section: 30 feet massive sandstone.
6 in. black slate.
24 in. coal.
Shale bottom.

Examination No. 11.

Property: Robert Helton.

Location: One-half mile above Buckhorn, Perry County, Ky., on left hillside of Squabble Creek.

Elevation: Coal bloom, 950 feet A. T.

Description: Fireclay coal. Slight excavations uncovered a very pronounced coal bloom. No coal faced. This coal is very probably an important one, and should be investigated thoroughly.

Coal Section: Shale roof.
Coal bloom.
Blue slate.
Thick massive sandstone bottom.

Examination No. 12.

Property: James F. Sandlin.

Location: Head of left fork of Schoolhouse branch, just east of old cabin on hillside, just above branch waters, Perry County, Ky.

Elevation: Coal, 1,000 feet A. T.

Description: Cannel slate, domestic opening of three feet. Not opened to solid face. The cannel shale found at this and other localities on Squabble and Otter Creeks is not a real cannel coal. Small splinters will occasionally ignite from a match, but the "shale" generally is too low in bituminous matter to burn freely in a grate. Not a commercial coal in this locality.

Coal Section: Gray shale roof.
12 in. cannel shale.
6 in. gray slate.
19 in. cannel shale.
5 in. gray slate.
21 in. cannel shale.
5 feet shale bottom.
18 in. coal (bituminous and good quality).
Sandstone bottom.

Examination No. 13.

Property: Jack Gross.

Location: Three-fourths of a mile up Squabble Creek and just at limits of Buckhorn, Perry County, Ky., on right side of creek.

Elevation: Coal, 760 feet A. T.

Description: Whitesburg coal. Small domestic mine, Well timbered and drained. Except for its thinness, this coal can be recommended from every angle. Very large acreage, high quality, and good roof. Measured 30 feet inside main entry. Reported thicker at face. Sampled. See analysis.

Coal Section: 30-foot massive sandstone } roof.
4 feet black slate. }
33 inches coal.
Gray slate bottom.

Examination No. 14.

Property: O. B. Anderson.

Location: On Buck Branch, 2 miles below Buckhorn, Perry County, Ky., one-fourth mile up creek.

Elevation: Coal, 745 feet A. T.

Description: Whitesburg coal. Domestic opening, well drained. Not a commercial coal in this locality.

Coal Section: 30-foot massive sandstone } roof.
6 in. to 24 in. gray-black shale. }
20 in. coal.
Shale bottom.

Examination No. 15.

Property: O. B. Anderson.

Location: On Buck Branch, 2 miles below Buckhorn, Perry County, Ky., three-fourths mile above mouth and Middle Fork of Kentucky River.

Elevation: Coal, 955 feet A. T.

Description: Fireclay coal. Domestic opening, partly timbered and somewhat fallen in. Badly impounded with water. A fine coal and very commercial. Sampled 50 feet from main opening, at face.

THE WHITESBURG COAL AT BUCKHORN.
This is a domestic mine on the Jerry Gross farm on Squabble Creek. The coal is 33 inches thick and is solid.

Coal Section: Sandstone roof.
28 in. coal.
4 in. bone.
12 in. coal.
Shale bottom.

Examination No. 16.

Property: G. R. Johnson.

Location: On Cam Johnson Branch, 2 miles above mouth, Perry County, Ky.

Elevation: Coal, 1,010 feet A. T.

Description: Fire Clay Rider coal. Comparatively new domestic opening half-way up right hill. Coal sharp and clean and solid. A commercial coal of good sized acreage, though carrying at this point a rather thick shale parting. Sampled. See analysis.

Coal Section: Gray shale roof.
25 in. coal.
14 in. gray shale.
20 in. coal.
Gray shale bottom.

Examination No. 17.

Property: Elihu Reynolds, 100 acres.

Location: On the Riley Fork of Long's Creek of Middle Fork of the

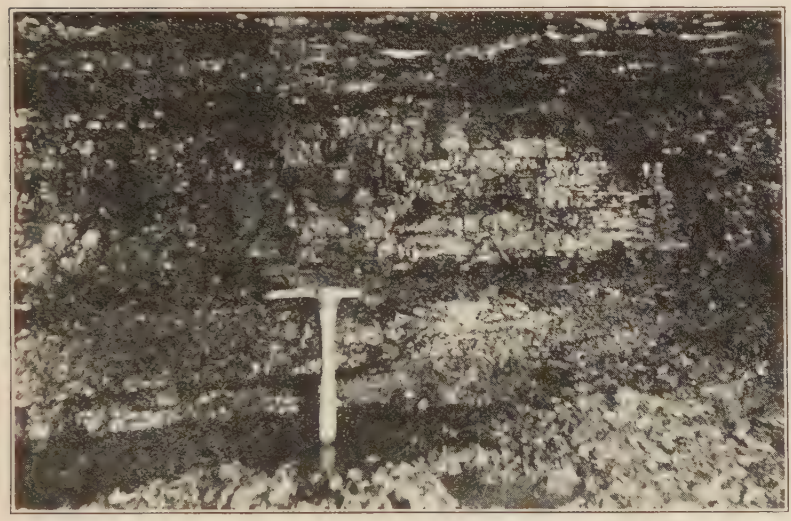
Kentucky River, Breathitt County, Ky.

Elevation: Coal, 750 feet A. T.

Description: Whitesburg coal. Private domestic mine 40 feet in rear of dwelling house. A very large acreage of this coal is to be found in ths locality, but it is not considered a commercial seam at the present time, due to its thinness and parting. Photographed and sampled. See analysis.

Coal Section: Gray-black shale roof.

20 in. coal.
6 in. gray shale.
8 in. coal
Gray shale bottom.



FACE OF THE WHITESBURG SEAM.

This opening is on the farm of Elihu Reynolds on the Riley Fork of Long's Creek. It is 28 inches thick here and of domestic importance only.

Examination No. 18.

Property: Elihu Reynolds, 200 acres.

Location: On Johnson Fork of Long's Creek, Breathitt County, Ky., one-half way up left hillside, in hollow back of farm house.

Elevation: Coal, 990 feet A. T.

Description: Hamlin coal. New opening. Not faced to solid. Coal would undoubtedly be thicker if driven to the solid. Acreage not large, due to relatively high position on the hill. Coal shows considerable parting, but otherwise very good, though not thick.

Coal Section: Shale roof.
8 in. coal.
4 in. gray shale.
4 in. black bone.
19 in. coal.
8 feet shale bottom.
21 in. coal.
Gray shale bottom.

Examination No. 19.

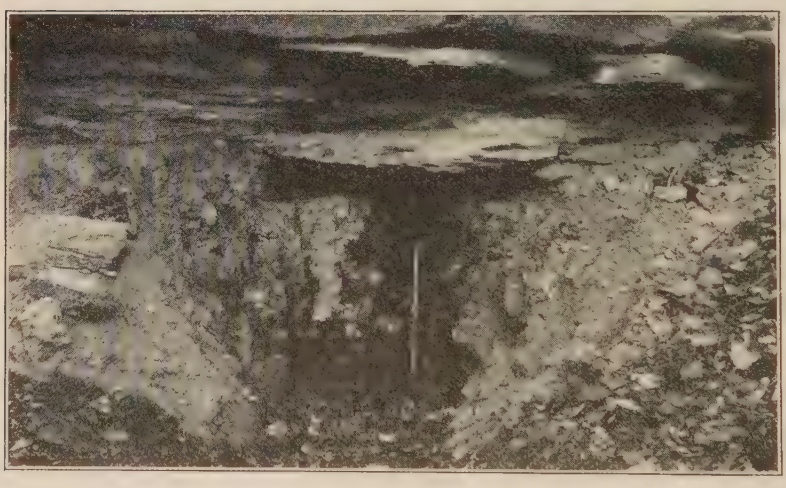
Property: Elihu Reynolds, 200 acres (same farm as No. 18).

Location: On Johnson Fork of Long's Creek, Breathitt County, Ky., about two-thirds of the way up left hillside below house.

Elevation: Coal, 1,170 feet A. T.

Description: Haddix coal. New opening. Not faced to the solid. Coal would undoubtedly be thicker if driven back. Acreage not large, due to relatively high position on the hill. Photographed.

Coal Section: Massive sandstone and shale roof.
1 in. shale.
34 in. coal.
Shale bottom.



COAL PROSPECT ON JOHNSON'S FORK OF LONG'S CREEK.
This coal is probably the Haddix. It is found on the Elihu Reynolds farm at an elevation of 1,170 feet and is 34 inches solid.

Examination No. 20.

Property: Berry Turner, Sr.

Location: 1 mile below Crockettsville, Breathitt County, Ky., on Groundhog Branch of Long's Creek, high in hillside of left fork near waterfall.

Elevation: Coal, 1,085 feet A. T.

Description: Hazard coal. Old domestic opening, partly water filled. Acreage small in this locality, due to elevation, but probably much larger toward the head of Long's Creek and other adjoining drainage. Some sulphur in thin partings. Sampled from the bottom 22 in. of "gray splint." See analysis.

Coal Section: 30 foot massive sandstone roof.

16 in. gray slate.
17 in. coal.
8 in. gray slate.
7 in. coal.
12 in. slate and coal.
11 in. coal.
6 in. slate.
22 in. coal ("gray splint").

THE HAZARD COAL—57 INCHES.
The opening is a domestic one on the Berry Turner farm on Groundhog Branch at an altitude of 1,085 feet.

Examination No. 21.

Property: Richard Combs, Sr.

Location: On Bowling's Creek, Breathitt County, Ky., one and three-fourths miles above mouth, about half-way up left hillside in hollow back of house.

Elevation: Coal, 945 feet A. T.

Description: Hamlin coal. Old domestic opening, partly timbered, partly water filled. Fair sized acreage. Sampled. See analysis.

Coal Section: Slate roof.
9 in. coal.
1 in. slate.
24 in. coal.
8 in. slate.
8 in. coal.
4 in. slate.
6 in. coal.
6 in. coal (under water).
Slate bottom.

Examination No. 22.

Property: G. B. Turner.

Location: On headwaters of Bowling's Creek, Breathitt County, Ky., one mile down stream from the gap.

Elevation: Coal, 945 feet A. T.

Description: Fireclay Rider coal. New, domestic opening. Not finished. Small amount of water impounded. A fine coal, evidently, but not thick enough at this point to be commercial. This coal reported to be 30 in. in opening, now fallen in, closed, and abandoned. Sampled. See analysis.

Coal Section: Gray slate roof.
1 in. black slate.
29 in. coal.
4 in. black slate.
Shale bottom.

Examination No. 23.

Property: Widow Mary Riley.

Location: On Bush Branch of the North Fork of the Kentucky River, Breathitt County, Ky., one and one-half miles above mouth of creek, and 20 feet above waters of the creek.

Elevation: Coal, 960 feet, A. T.

Description: Fireclay Rider Coal. Old domestic opening, badly fallen in, impounding considerable water. Not a commercial coal.

Coal Section: Slate roof.
21 in. coal.
6 in. (coal?) water covered.
4 feet black shale bottom.

Examination No. 24.

Property: Ed Turner.

Location: On Bush Branch of North Fork of Kentucky River in Breathitt County, Ky., one and one-fourth miles above creek mouth, and 40 feet above waters of creek.

Elevation: Coal, 950 feet A. T.

Description: Fireclay Rider coal. Old domestic opening, very badly fallen in, impounding large amount of water. Measured at 4 feet inside of main entry.

Coal Section: Gray shale roof.
25 in. coal.
6 in. (coal?) water covered.
Shale bottom.

THE FIRE CLAY RIDER ON BUSH BRANCH.
This seam is here well up on the hillside. It is operated by the Deaton Coal Co.

Examination No. 25.

Property: Deaton Coal Co.

Location: On Bush Branch of North Fork of the Kentucky River, in left hillside just above Altro, and one-half mile above mouth of creek and L. & N. R. R.

Elevation: Coal, 940 feet, A. T.

Description: Fireclay Rider coal. Commercial mine—not being operated at present. Main entry drifted in through coal and 2 feet of shale in bottom to give mule room and drainage. Sampled.

Coal Section: Gray slate roof.
32 in. coal.
Gray slate bottom.

Examination No. 26.

Property: Ballinger-Jones Coal Co.

Location: On the right, at the mouth of Eversole Creek, Perry County, Ky. (Davies Station.)

Elevation: Coal, 930 feet, A. T. on spur.

Description: Fire Clay Rider coal. Operating mine. Excellent roof, good property. Sampled and analyses attached to report.

Coal Section: Gray slate roof.
29 inches coal, clean.
Gray shale bottom.
Fire clay.

Examination No. 27.

Property: Johnson-Hogg Coal Co.

Location: Up branch one-sixteenth mile on right of Eversole Creek, Perry County, Kentucky.

Elevation: Coal 935 feet A. T.

Description: New facing of Fire Clay or No. 4 coal and Fire Clay Coal Rider.

Coal Section: Rider Coal.
Sandstone 8 feet.
2 feet shale roof.
40 inches coal, clean.
Shale bottom.

Examination No. 28.

Property: Johnson-Hogg Coal Co.

Location: Main Entry,[1] just above drainage one and one-half miles up Eversole Creek on the right.

Elevation: Coal 925 feet, A. T.

Description: Old-main entry and operating face of Fire Clay coal or No. 4 coal. Sampled at 2,300 feet in, analyses attached.

Coal Section: Shale roof.
A 33 in. coal, clean.
1½ or 2 in. black jack rock (2,300 feet in).
20 in. coal, clean.
Shale bottom.

Examination No. 29. (Same mine as No. 3.)

Coal Section: Shale roof.
B 48 in. coal, clean.
4 in. black jack rock. (100 feet in on left side entry called "Dog House").
44 in. coal, clean.
Shale bottom.

Note: Alt. of lowest point in the divide between Eversole and Gays Creeks—Stump by side of road 1,510 feet, Bar.

Examination No. 30.

Property: Joseph Sandlin farm.

Location: On the left at the bottom of the hill road to Eversole Creek on the headwaters of Gays Creek.

[1]Note: At this point from 8 to 16 feet separate the Fire Clay or (No. 4) coal from its Rider.

DOMESTIC OPENING ON BOWLING CREEK.
There is 43 inches of coal in this seam on the Richard Combs farm but it is split by three shale partings.

Elevation: Coal, 955 feet, A. T.

Description: Fire Clay or No. 4 coal and Fire Clay Rider coal. Domestic opening. Sampled and analyses attached. Commercial.

Coal Section: Shale roof.

24 in. coal, clean.
Shale bottom
12 in. parting.
Fire Clay coal (No. 4).
Shale roof.
30 in. coal, clean.
7 in. black jack rock.
13 in. coal.
Fire Clay bottom.

Examination No. 31.

Property: H. M. Begley farm.

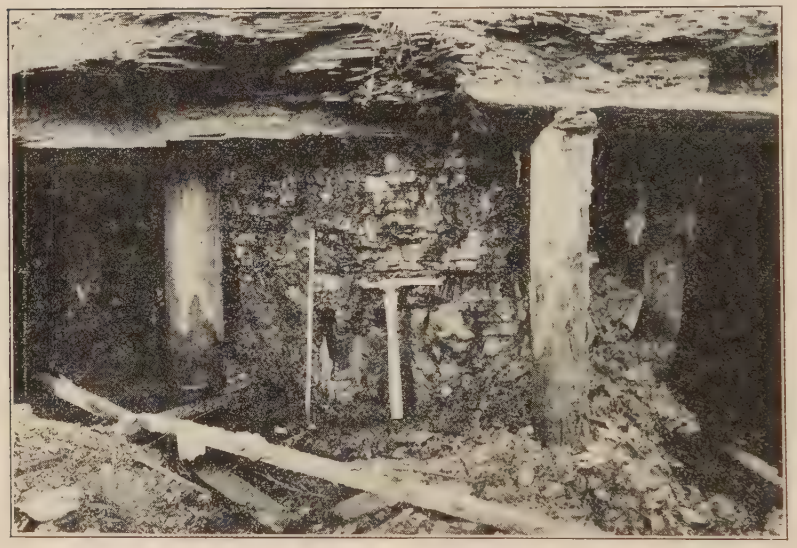
Location: On the left on the hill below schoolhouse on the right fork of Gays Creek, Perry County, Kentucky. One and one-half miles above mouth of the Creek.

Elevation: Coal, 955 feet, A. T.

Description: Fire Clay Rider coal. Domestic opening.

Coal Section: Shale roof.
21 in. coal.
1 in. soft shale, black.
12 in. coal.
Shale bottom.

Note: The Fire Clay or No. 4 coal is indicated by quantities of seepage water 15 feet below the above described Rider seam. It has not been opened at this place, however.



This is the main entry of the Jim Sandlin domestic mine at Buckhorn, Perry County, Kentucky.

Examination No. 32.

Property: L. Stanley farm.

Location: On right fork of Gays Creek one and one-fourth miles above mouth, Perry County, Kentucky.

Elevation: Coal, 800 feet, A. T.

Description: Stray coal un-named. Domestic opening under Black shale cliff on left of creek.

Coal Section: Black shale roof.
4 in. bone coal.
3 in. soft black shale.
16 in. coal.
Shale bottom
Massive sandstone.

Examination No. 33.

Property: Sam Morris farm.

Location: On left fork of Gays Creek just above forks on the left-hand hillside above dwelling.

Elevation: Coal, 960 feet, A. T.

Description: Fire Clay or No. 4 coal. Good domestic opening, badly impounded with water. Sampled and analyses attached.

Coal Section: Shale roof (hard and firm).

27 in. coal, clean.

5 in. shale and bone (lock rock).

12 in. coal.

Shale bottom.

Fire Clay—10–24 in. thick generally.

First note: The Fire Clay Coal Rider is exposed just a few feet above this coal. It is considered uncommercial at 18 inches in thickness.

Second note: This same farm (Sam Morris) at elevation of 1,075 and directly above the opening of examination No. 33 shows coal bloom at a fresh slip. This is probably the Hamlin coal but not being faced it could not positively be determined.

FIRE CLAY RIDER COAL ON CAM JOHNSON BRANCH.
This Domestic opening shows 45 inches of coal and a 14-inch shale parting at an altitude of 1010 feet.

Examination No. 34.

Property: John M. Begley farm.

Location: On the head of Paw Paw hollow of the right fork Gays Creek, Perry County, Ky.

Elevation: Coal 1,385 feet, A. T.

Description: Hindman or No. 9 coal. Excellent prospect opening. Impounded with water and could not drain to sample. This coal is 425 feet above the Fire Clay (No. 4) coal. Very limited area.

Coal Section: Sandstone roof.

23 in. coal.
2 in. black shale.
11 in. coal.
Shale (hard) bottom.

Examination No. 35.

Property: Johnson-Hogg Coal Co.

Location: On Eversole Creek up left hollow at Main Mine, Perry County, Kentucky.

Elevation: Coal, 1,150 feet, A. T.

Description: Haddix or No. 5 coal main mine entry, 100 feet in.

Coal Section: Slate roof.

24 in. coal.
Shale bottom.

Examination No. 36.

Property: Johnson-Hogg Coal Co.

Location: On Eversole Creek up left hollow at Main Mine, Perry County, Ky.

Elevation: Coal 1,250 feet, A. T.

Description: Hazard coal or No. 6. Main entry of mine 75 feet in. Coal sampled and analyses attached.

Coal Section: Shale roof.

15 in. coal.
1 in. black shale.
4 in. coal.
4 in. shale (hard) (jack rock).
16 in. coal.
Shale bottom.

Examination No. 37.

Property: Owner unknown.

Location: Head of right fork of Gays Creek at left of ford on hillside.

Elevation: Coal 1,350 feet, A. T.

Description: Francis coal or No. 8 coal bloom and water—unopened.

Examination No. 38.

Property: Owner unknown.

Location: Head of right fork of Gays Creek at left of road on hillside.

Elevation: Coal 1,315 feet, A. T.

Description: Flag or No. 7 coal bloom and water—unopened.

Examination No. 39.

Property: H. M. Begley heirs.

Location: Head of right fork of Gays Creek at left of road on hillside.

Elevation: Coal, 1,250 feet, A. T.

Description: Hazard or No. 6 coal. Sandstone roof badly fallen in. Old domestic opening could not measure as entry was closed. Reported 40 in.

Examination No. 40.

Property: Owner unknown.

Location: On left of Gays Creek, three-fourths mile above mouth, 8 feet above drainage under massive sandstone ledge, Perry County, Ky.

Elevation: Coal 770 feet A. T.

Description: Whitesburg or No. 3 coal. Old domestic opening underneath massive sandstone ledge. Not a commercial coal here.

Coal Section: Sandstone 30 feet massive.
1 foot shale (black) roof.
18 in. coal.
Shale bottom.

Analyses of the Coals.

In making the collections of samples for analysis, the coals were "channel sampled" down the entire face wherever it was possible to do so. In some "wet" openings only block samples could be taken. The analyses were made principally by W. D. Iler, under the direction of Dr. A. M. Peter, Chief Chemist at the State Agricultural Experiment Station, Lexington, Ky.

HAZARD COAL.

Analysis No. 1.

Coals (Nos. 1 and 2) received February 9, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4043, labeled "Top 15 in. ridge seam 1,210 ft. on John Gross Farm on Middle Fork of Ky. River just below the mouth of Otter Creek, Perry County, Ky. Collected by W. R. Jillson, Feb. 5, 1921." Sample in two lumps.

Analysis No. 2.

Laboratory No. G-4044, labeled "Bottom 51 inches. Ridge seam 1,210 feet on John Gross farm on Middle Fork of Ky. River just below mouth of Otter Creek, Perry Co., Ky. Collected by W. R. Jillson, Feb. 5, 1921." Sample one large lump.

Analyses of the Air-dried Sample.

	Per cent.	
	G-4043	G-4044
Moisture	2.23	2.52
Volatile combustible matter	39.56	29.23
Fixed carbon	51.32	62.00
Ash	6.89	6.25
Total	100.00	100.00
Sulfur	4.51	1.50
B. T. U. per pound	12,500	12,800
Color of ash	Purplish-red	Reddish-buff

G-4043 Fuel ratio $\frac{51.32}{39.56} = 1:1.3$

G-4044 Fuel ratio $\frac{62.00}{29.23} = 1:2.1$

(Analyses by W. D. Iler)

WHITESBURG COAL.

Analysis No. 3.

Coal received February 10, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4045, labeled "From the Jack Gross mine in right bank of Squabble Creek, Buckhorn, Perry County, Ky. Collected by W. R. Jillson, Feb. 6/21."

Analysis.

	Air-dry	Moisture-free
Moisture	1.43	....
Volatile combustible matter	40.15	40.73
Fixed carbon	52.86	53.63
Light-gray ash	5.56	5.64
Total	100.00	100.00
Sulfur	1.85	1.88
B. T. U. per pound	13,840.	14,040.

Fuel ration = 1:1.3

(Analysis by W. D. Iler.)

FIRE CLAY RIDER COAL.

Analysis No. 4.

Coal, received February 10, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4046, labeled "From schoolhouse seam about 1,000 feet left bank of Squabble Creek, Buckhorn, Ky. Collected by W. R. Jillson, 2/7/21."

Gray Slate Roof
'5 In Coal
12 In Gray Slate.
5' In Coal.
Sandstone Bottom
Ex. No. 1.
John Gross.
Gray Slate Roof
16 In. Coal.
½ In Slate Parting.
19 In Coal.
Gray Slate Bottom.
Ex. No. 2.
Jim Sondlin
Gray Slate Roof.
38 In. Coal.
Gray Slate Bottom.
Ex. No. 3.
Floyd Gross.
30 Ft. Gray Sandstone.
31 In. Coal.
Shale Bottom.
Ex. No. 4.
John Gross.
Sandstone Roof
19 In. Coal.
6 Ft. Slate.
14 In. Coal.
Shale Bottom.
Ex. No. 5.
Lewis Strong
Slate Roof.
38 In. Coal.
4 In. Gray Slate.
12 In. Coal.
Sandstone Bottom.
Ex. No. 6.
Levi Strong.
Coal Sections.
Breathitt and Perry Co's, Ky.
1

ANALYSIS.

	Air-dry	Moisture-free
Moisture	2.37	....
Volatile combustible matter	37.90	38.82
Fixed carbon	58.20	59.61
Greenish colored ash	1.53	1.57
Total	100.00	100.00
Sulfur	0.95	0.97
B. T. U. per pound	14,100.	14,440.

Fuel ratio=1:1.5

(Analysis by W. D. Iler.)

FIRE CLAY RIDER COAL.

Analysis No. 5.

Coal, received February 14, 1921, from W. R. Jillson, State Geologist, as follows:

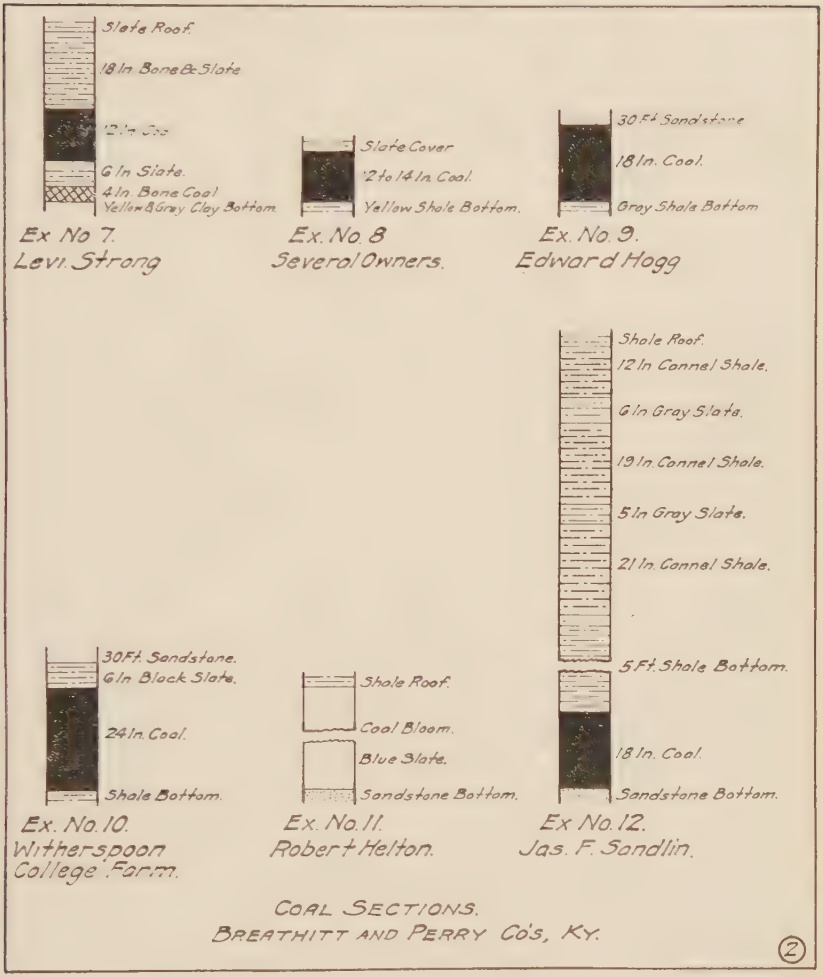
Laboratory No. G-4047, labeled "G. R. Johnson farm about 1,010 ft. on Cam Johnson Br. Collected by W. R. Jillson, Feb. 8/21. Perry Co., Ky."

ANALYSIS.

	Air-dry	Moisture-free
Moisture	1.96	....
Volatile combustible matter	36.23	36.95
Fixed carbon	56.93	58.07
Buff colored ash	4.88	4.98
Total	100.00	100.00
Sulfur	0.76	0.78
B. T. U. per pound	13,440.	13,710.

Fuel ration=1:1.6

(Analysis by W. D. Iler.)



WHITESBURG COAL.

Analysis No. 6.

Coal, received February 14, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4048, labeled "Sample from Elihu Reynolds on Riley Fork of Long's Creek on Middle Fork of Kentucky River, Breathitt County, Ky. Collected by W. R. Jillson, 2/8/21. Abt. 750."

Analysis.

	Air-dry	Moisture-free
Moisture	1.71	....
Volatile combustible matter	40.75	41.46
Fixed carbon	52.70	53.62
Purple colored ash	4.84	4.92
Total	100.00	100.00
Sulfur	3.45	3.51
B. T. U. per pound	13,470.	13,700.

Fuel ration = 1:1.3

(Analysis by W. D. Iler.)

FIRE CLAY COAL.

Analysis No. 7.

Coal, received February 14, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4049, labeled "O. B. Anderson's farm, Buck Branch of Middle Fork of Kentucky River, 2 miles below Buckhorn, Ky. 2/8/21. Collected by W. R. Jillson."

Analysis.

	Air-dry	Moisture-free
Moisture	2.03	....
Volatile combustible matter	36.62	37.37
Fixed carbon	59.53	60.77
Reddish colored ash	1.82	1.86
Total	100.00	100.00
Sulfur	0.84	0.86
B. T. U. per pound	14,090.	14,380.

Fuel ration = 1:1.6

(Analysis by W. D. Iler.)

FIRE CLAY RIDER COAL.

Analysis No. 8.

Coal, received February 14, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4050, labeled "Sample from 30 feet inside main entry of upper mine of Deaton Coal Co., one-half mile above mouth of Bush Branch of the North Fork of the Kentucky River, Breathitt County, Ky., Bar. Alt. 940 feet. Collected by W. R. Jillson, 2/9/21."

Analysis.

	Air-dry	Moisture-free
Moisture	2.41	....
Volatile combustible matter	34.85	35.71
Fixed carbon	58.18	59.62
Pinkish-gray ash	4.56	4.67
Total	100.00	100.00
Sulfur	0.91	0.93
B. T. U. per pound	13,390.	13,720.

Fuel ratio = 1:1.7

(Analysis by W. D. Iler.)

FIRE CLAY RIDER COAL.

Analysis No. 9.

Coal, received February 14, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4051, labeled "Sample of coal from whole face 8 feet, head of entry on the G. B. Turner farm, 1 mile from head of Bowling's Creek, Alt. 945 ft. Breathitt Co., Ky. Collected by W. R. Jillson, 2/9/21."

Analysis.

	Air-dry	Moisture-free
Moisture	1.93	....
Volatile combustible matter	30.82	31.43
Fixed carbon	54.31	55.38
Light-gray ash	12.94	13.19
Total	100.00	100.00
Sulfur	1.18	1.20
B. T. U. per pound	12,180.	12,420.

Fuel ratio = 1:1.8

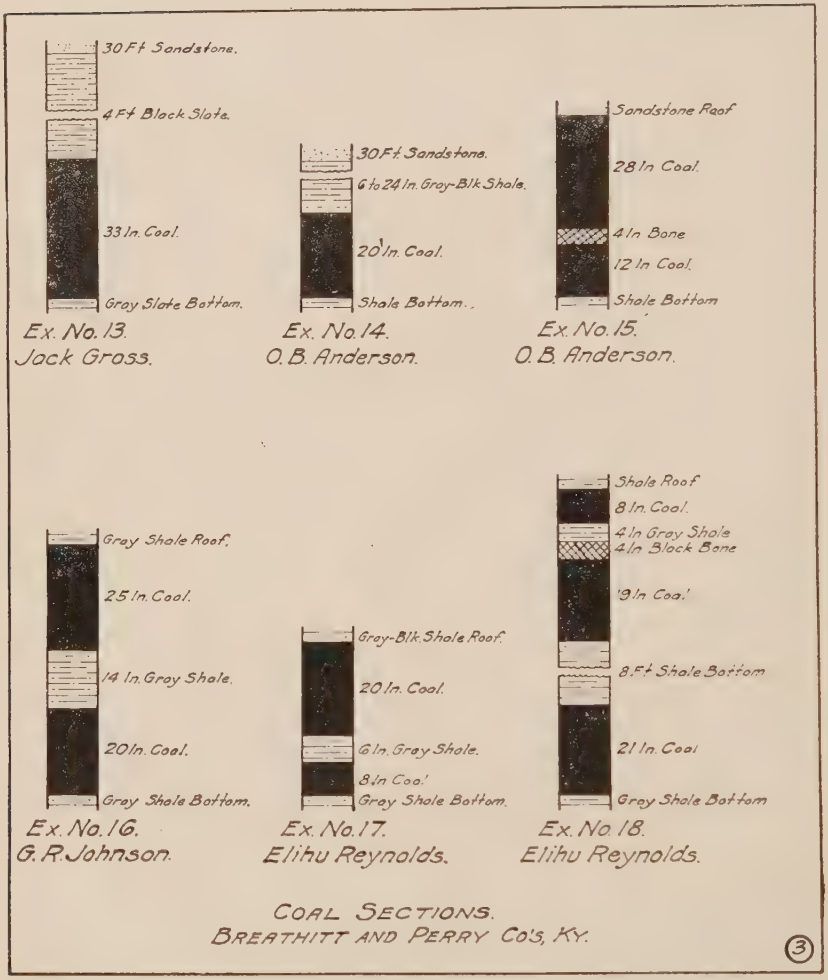
(Analysis by W. D. Iler.)

HAZARD COAL.

Analysis No. 10.

Coal, received February 14, 1921, from W. R. Jillson, State Geologist, as follows:

Laboratory No. G-4052, labeled "Sample of 'gray splint' from below lower shale parting taken from poorly faced domestic opening on the Berry Turner, Sr., farm located on headwaters of the Groundhog Branch of Long's Creek of the Middle Fork of the Kentucky River, Breathitt County, Ky. Bar. Alt. 1,075 feet. Collected by W. R. Jillson, 2/9/21."


30 Ft Sandstone.
4 Ft Black Slate.
33 In. Coal.
Gray Slate Bottom.
Ex. No. 13.
Jack Gross.
30 Ft Sandstone.
6 to 24 In. Gray-Blk. Shale.
20 In. Coal.
Shale Bottom.
Ex. No. 14.
O. B. Anderson.
Sandstone Roof
28 In. Coal.
4 In Bone
12 In Coal.
Shale Bottom
Ex. No. 15.
O. B. Anderson.
Gray Shale Roof.
25 In. Coal.
14 In. Gray Shale.
20 In. Coal.
Gray Shale Bottom.
Ex. No. 16.
G. R. Johnson.
Gray-Blk. Shale Roof.
20 In. Coal.
6 In. Gray Shale.
8 In Coal
Gray Shale Bottom.
Ex. No. 17.
Elihu Reynolds.
Shale Roof
8 In. Coal.
4 In Gray Shale
4 In Black Bone
9 In Coal
8 Ft Shale Bottom
21 In Coal
Gray Shale Bottom
Ex. No 18.
Elihu Reynolds.
Coal Sections.
Breathitt and Perry Co's, Ky.
3

ANALYSIS.

	Air-dry	Moisture-free
Moisture	2.15	....
Volatile combustible matter	36.01	36.80
Fixed carbon	54.69	55.89
Reddish-gray ash	7.15	7.31
Total	100.00	100.00
Sulfur	1.66	1.70
B. T. U. per pound	12,880.	13,170.

Fuel ratio = 1:1.5

(Analysis by W. D. Iler.)

HAZARD COAL.

Analysis No. 11.

Coal, received April 23, 1921, from W. R. Jillson, State Geologist. Laboratory No. G-4054, labeled "Sample of coal stripped from entire face of coal No. 6 from the Johnson-Hogg property 1 mile up from mouth of creek on left of Eversole Creek, Perry County, Kentucky. Collected by W. R. Jillson, April 21, 1921."

ANALYSIS.

	Air-dry	Moisture-free
Moisture	4.49	....
Volatile combustible matter	30.51	31.94
Fixed carbon	54.72	57.30
Ash	10.28	10.76
Total	100.00	100.00
Sulfur	0.79	0.81
B. T. U. per pound	11,770.00	12,320.00
Color of ash	pink	
Fuel ratio $\left\{\begin{array}{l}\text{fixed carbon}\\ \text{volatile combustible matter}\end{array}\right\}$	1.8	

(Analysis by W. D. Iler.)

FIRE CLAY COAL.

Analysis No. 12.

Coal, received April 23, 1921, from W. R. Jillson, State Geologist. Laboratory No. G-4055, labeled "Sample from entire face of No. 4 or Fire Clay coal from the entire coal face of Johnson-Hogg Co. mines on Eversole Creek, at left one mile above mouth of Creek. Sample collected by W. R. Jillson from face of main entry 2,300 feet in. April 20, 1921. Perry County, Kentucky."

ANALYSIS.

	Air-dry	Moisture-free
Moisture	3.12	....
Volatile combustible matter	34.06	35.16
Fixed carbon	58.36	60.24
Ash	4.46	4.60
Total	100.00	100.00
Sulfur	1.08	1.11
B. T. U. per pound	13,180.00	13,500.00
Color of ash	Yellowish gray	
Fuel ratio { fixed carbon / volatile combustible matter }	1.7	

(Analysis by W. D. Iler.)

FIRE CLAY COAL.

Analysis No. 13.

Coal, received April 23, 1921, from W. R. Jillson, State Geologist. Laboratory No. G-4056, labeled "Sample of No. 4 or Fire Clay coal Rider from Ballinger-Jones Co. mine, mouth of Eversole Creek, north fork Kentucky River, Perry County, Kentucky. Collected by W. R. Jillson, from entire face of coal. April 20, 1921."

ANALYSIS.

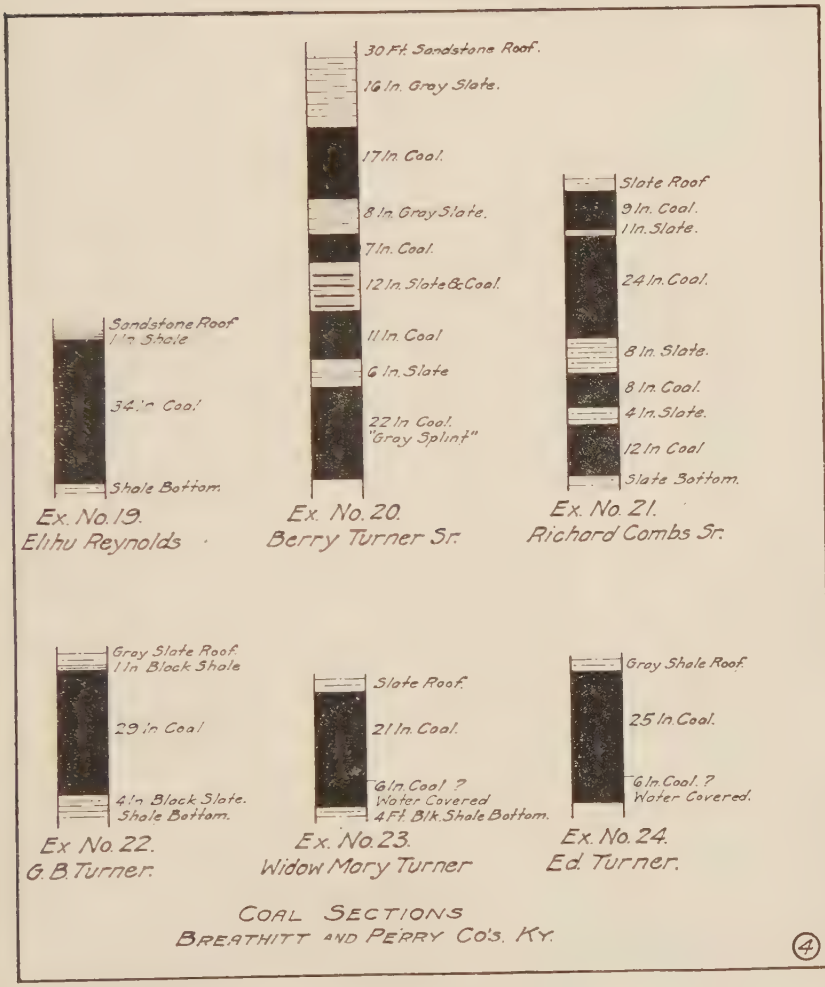
	Air-dry	Moisture-free
Moisture	2.81	....
Volatile combustible matter	37.39	38.47
Fixed carbon	53.36	54.90
Ash	6.44	6.63
Total	100.00	100.00
Sulfur	1.15	1.18
B. T. U. per pound	12.910.00	13,270.00
Color of ash	Very light brown	
Fuel ratio { fixed carbon / volatile combustible matter }	1.4	

(Analysis by W. D. Iler.)

FIRE CLAY COAL.

Analysis No. 14.

Coal received April 23, 1921, from W. R. Jillson, State Geologist. Laboratory No. G-4057, labeled "Sample stripped from entire face of No. 4 or Fire Clay coal, 30 feet back in main entry of domestic opening on the farm of Sam Morris, left fork of Gays Creek, Perry Co., Ky. Collected by W. R. Jillson, 4/21/21."


Sandstone Roof.
1 In. Shale
34 In. Coal
Shale Bottom.
Ex. No. 19.
Elihu Reynolds
30 Ft. Sandstone Roof.
16 In. Gray Slate.
17 In. Coal.
8 In. Gray Slate.
7 In. Coal.
12 In. Slate & Coal.
11 In. Coal
6 In. Slate
22 In. Coal.
"Gray Splint"
Ex. No. 20.
Berry Turner Sr.
Slate Roof
9 In. Coal.
1 In. Slate.
24 In. Coal.
8 In. Slate.
8 In. Coal.
4 In. Slate.
12 In Coal
Slate Bottom.
Ex. No. 21.
Richard Combs Sr.
Gray Slate Roof.
1 In. Black Shale
29 In Coal
4 In. Black Slate.
Shale Bottom.
Ex No. 22.
G. B. Turner.
Slate Roof.
21 In. Coal.
6 In. Coal ?
Water Covered
4 Ft. Blk. Shale Bottom.
Ex. No. 23.
Widow Mary Turner
Gray Shale Roof.
25 In. Coal.
6 In. Coal. ?
Water Covered.
Ex. No. 24.
Ed. Turner.
COAL SECTIONS
BREATHITT AND PERRY Co's. KY.
4

Analysis.

	Air-dry	Moisture-free
Moisture	3.83	....
Volatile combustible matter	33.07	34.39
Fixed carbon	57.65	59.95
Ash	5.45	5.66
Total	100.00	100.00
Sulfur	0.70	0.73
B. T. U. per pound	12,920.00	13,430.00
Color of ash	flesh colored	
Fuel ratio $\left\{\begin{array}{l}\text{fixed carbon}\\ \text{volatile combustible matter}\end{array}\right\}$	1.7	

(Analysis by W. D. Iler.)

FIRE CLAY COAL.

Analysis No. 15.

Coal received April 26, 1921, from W. R. Jillson, State Geologist. Laboratory No. G-4058, labeled "Channel Stripped sample of No. 4 or Fire Clay coal from the Joseph Sandlin farm on the headwaters of Gays Creek, Perry County, Ky. Collected by W. R. Jillson, State Geologist, April 22, 1921."

Analysis.

	Air-dry	Moisture-free
Moisture	2.67	....
Volatile combustible matter	31.96	32.83
Fixed carbon	59.16	60.79
Ash	6.21	6.38
Total	100.00	100.00
Sulfur	0.84	0.86
B. T. U. per pound	13,060.00	13,420.00
Color of ash	Very light gray	
Fuel ratio $\left\{\begin{array}{l}\text{fixed carbon}\\ \text{volatile combustible matter}\end{array}\right\}$	1.85	

(Analysis by W. D. Iler)

FLAG AND FIRE CLAY COALS.

Analysis Nos. 16 and 17.

Two coals received June 25, 1921, from W. R. Jillson, State Geologist, from the Johnson-Hogg Coal Company, Chavies, Perry County, Ky.

Laboratory No. G-4060, labeled "Hazard No. 4 or Fire Clay coal, J. E. Johnson, 623 East High St., Lexington, Ky."

Laboratory No. G-4061, labeled "No. 7 (Flag) coal, J. E. Johnson, 623 East High St., Lexington, Ky."

ANALYSIS OF THE AIR-DRY SAMPLE.

	Per cent.	
	Fire Clay Coal G-4060	Flag Coal G-4061
Moisture	2.40	2.26
Volatile combustible matter	35.90	32.96
Fixed carbon	57.41	46.15
Ash	4.29	18.63
Total	100.00	100.00
Color of ash	Yellowish-gray	Grayish brown
Sulfur	0.92	1.06
B. T. U. per pound	13,170.00	10,430.00

(Analyses by W. D. Iler and S. D. Averitt)

EVALUATION AND COMMERCIALIZATION OF THE MIDDLE FORK COALS.

As a result of the field investigations made, several of the eleven separate coals of this section are found to be commercial in the Buckhorn region on the waters of the Middle Fork of the Kentucky River and its tributaries. The recommendations made are based upon faithful measurements and accurate analyses.

Of chief commercial importance in this area, due to its thickness, lower elevation, and hence larger tonnage, is the No. 4, or Fire Clay coal. On the Middle Fork and its tributaries this coal is about 50 feet higher in the hills than it is on the North Fork of the Kentucky River, due to a deeper incision in this same figure of the drainage of the Middle Fork as compared to that of the North Fork. Acreages, therefore, of the No. 4 coal are somewhat less on the Middle Fork drainage than on the North Fork drainage. On Gays Creek the Fire Clay coal varies between 39 and 49 inches in thickness, thereby showing much less irregularity than it does on the Eversole Creek, where in the mines of the Johnson-Hogg Coal Company it was measured at 92 inches of clean coal at a maximum, and ranged down to 53 inches, as a minimum. It always shows a black, very hard "Jack rock" parting, which averages from 3 to 8 inches on Eversole Creek but is con-

LOG TRANSPORTATION ON LONG'S CREEK.
During the periods of low water, oxen are used to transport the best timber from the heads of the creeks to the river.

siderably less on the Middle Fork. On Gays Creek the Fire Clay coal shows low in sulphur at .70; low in ash at 5.45, and medium in B. T. U.'s at 12,920. An analysis of the Fire Clay coal from the Joseph Sandlin farm on the head of Gays Creek shows it to be low in sulphur at .84; medium in ash at 6.21; and fairly high in B. T. U.'s at 13,060. The analysis as given for the Sam Moore's farm mine compares favorably with that of Sandlin's farm, the sulphur being lower at .70; the ash lower at 5.45; and B. T. U.'s lower at 12,920.

The coals of second importance to the Fire Clay coal are (1) the Fire Clay Rider coal, generally found from 20 to 40 feet above the Fire Clay coal, and averaging about 35 inches in thickness of clean coal, and (2) the Hazard or No. 6 coal, about 250 feet higher, which ranges between 40 and 66 inches with partings. The 40 inch thickness is reported from the completely fallen in structure upon the head of Gays Creek, and the 66-inch thickness was measured in the John Gross mine at the mouth of Gays and Otter Creeks on the Middle Fork

BUSH BRANCH, BREATHITT COUNTY, KY.

The view is nearly east toward the North Fork of the Kentucky River and well illustrates the human geography of the creeks of the Cumberland Plateau in Kentucky.

of the Kentucky River. The Hazard coal is very low in sulphur, but high at 10.28 in ash; and low in B. T. U.'s at 11,700. At an elevation of 1210 the largest acreage of the Hazard coal would be found up toward the head of the creeks and away from the Middle Fork itself, where the hills are somewhat lower. The Hazard coal is being operated by the Johnson-Hogg Coal Company on Eversole Creek. The Fire Clay Rider coal might be worked in conjunction with the Fire Clay coal, but it is not regarded as a commercial coal except in very restricted locations when taken separately.

VICTOR AND VANQUISHED.

The fierce struggle for existence is not confined to the animal kingdom. Here on Gay's Creek is a concrete example of the titanic strength of a white walnut sapling sprouted in the heart of a great block of Pottsville sandstone. Vegetation is one agent of rock weathering and decay.

The higher coals known to exist and examined within the area of this report will not be further discussed here, since they are considered to be of either too limited an acreage, or to have offered at this time too meager information, to warrant an authoritative generalization. These coals have already

been listed in sequence, and the detail of their occurrence has been recorded as separate examinations and analyses, to which the reader is referred for further information.

Aggregate Tonnage and Value.

For the entire area considered, which is figured at about 56 square miles, a thickness of 4 feet of coal is regarded as present and of commercial importance. This estimate, however, is low, rather than high. In many parts of this area, the total section of commercial coals can be measured to upwards of 6 and 7 feet. Figured, however, at 4 feet to the acre, 6,244,761,600 cubic feet for the area discussed is secured. This volume of coal, divided by the recognized bituminous coal factor of 24.6, gives a total of 253,852,097 short tons for this same area. This tonnage, if figured at a value of 1 penny per ton in the ground, which is commonly done in Kentucky, will give the enormous yet conservative value of $2,538,520.97 for the unmined coal considered within this report.

Transportation.

With the coals of this section definitely correlated, recognized, and appraised, the only deterrent factor to their immediate development and commercialization lies in the means of transportation. During the late 90's the stream flow of the Middle Fork of the Kentucky River was somewhat more uniform than at the present, due to the fact that the forest cover had not been so thoroughly removed. About this time a considerable amount of coal was annually moved from this section, in flat boats, down the river to Beattyville and beyond. With the development, however, of rail transportation up the North Fork of the Kentucky River, and the opening of the great Hazard and Elkhorn fields, the coals on the Middle Fork soon lost out in competition. The few small mines which were then operated close to the Middle Fork of the Kentucky River in this flat boat traffic were rapidly abandoned, and the industry became shortly a matter of history.

A KENTUCKY RIVER FORD.

There are no bridges above or below Beekhorn for miles. This ford of the Middle Fork of the Kentucky River is at the Mouth of Long's Creek.

Could new rail transportation be directed up the Middle Fork of the Kentucky River, either from Athol on the L. & N. Railroad, or from some other convenient higher point on the North Fork, the coals of the section adjacent to Buckhorn, and those farther up the Middle Fork in Leslie county, would become commercial at once, and prove a great and valuable additional mineral resource to this unexploited portion of the Eastern Kentucky Coal Field. Considered in a broad, general way, the coals improve in character and thickness as one progresses up the Middle Fork towards the head of the river, and any line projected into this section should take fully into consideration this very important point.

IV

THE
OIL POOLS OF WARREN COUNTY, KY.*

By Stuart St. Clair,
Assistant Geologist.

Introduction.

Prior to 1919 there were no producing oil wells in Warren County although there was considerable production in Allen County, the county adjoining on the east. A number of wells had been drilled in scattered localities from the eastern almost to the western edge of Warren County but the results had been unfavorable although some oil and gas had been found in the limestone underlying the Devonian black shale. The Jackson wells on Gasper River were probably the most notable of these early efforts and several wells were drilled, but the production was not of commercial size.

Naturally, oil development should start on the east side of the county nearest the producing fields of Allen County and scattered pools of Barren County. The Moulder pool, opened in the spring of 1919, furnished the first thrill. Wells of gusher type were brought in during this spring and summer from the top of the Corniferous limestone, which is subjacent to the Devonian black shale, at depths of little more than 400 feet. This started great activity in the area extending from Barren River north to Smiths Grove and west to the Three

*The Kentucky Geological Survey does not assume responsibility for any of the theories of oil migration from original sources which are advanced in this paper on Warren County.

OUTLINE MAP OF WARREN COUNTY.
The established oil pools and pipe lines of Warren County and the adjacent part of Allen County are shown.

Forks neighborhood. The early summer of 1919 saw many tests being made in other parts of eastern Warren County and a few small wells were struck just to the south of Rocky Springs school, about one mile west of Claypool, on the Williams, Motley, and adjoining farms.

A little later small wells on the Willoughby and Moody farms to the south were drilled in and also to the west in the Hardcastle area, on the Crow farm. Steady drilling has continued in the latter area ever since, although the wells are small. In the same summer a shallow well was drilled on the Covington farm on the Scottsville Pike near the Bowling Green city limits, oil of high grade coming from a "sand" at of depth of 355 feet. This discovery started drilling all around the city but nothing of commercial value was opened except

COLLEGE HEIGHTS PANORAMA.

The view is northwest and shows topography of the oil fields west of Bowling Green. The escarpment ridge can be seen in the distance and at its base are many good wells. The Little Briggs pool is in the foreground.

the small pool on the Thomas and Covington farms on the Smallhouse Pike, the production coming from probably the same shallow sand. No wells were developed in the sand below the Black Shale. Efforts in the southeastern part of the county near Drake post office were without commercial results. In the fall a small pool was opened up at Britts Mill, east of Claypool, in a sand probably equivalent to the Beaver, from which amber oil was produced, and also in the Corniferous sand below the shale. The discovery well in the Sledge pool in Allen County, near the Warren line, was drilled about this time.

On November 3, 1919, the discovery well on the Davenport farm, several miles northwest of Bowling Green on the Barren River Pike, was completed. The real development of Warren County dates from this time, although it was the spring and early summer of 1920 before the drilling campaign was in full swing. Deep wells have been drilled in the Davenport section and in a line south to the Dixie Highway with very encouraging results. In the early summer of 1920 a gusher was struck on the Tarrants farm, just east of the original Davenport, in a shallow and unknown "sand" at a depth of about 450 feet which added greatly to the boom already on. Wells in this shallow sand have been struck continuously in this section ever since. During the summer of 1920 additional shallow pools were opened in the McGinnis-Wilson area, west

BARREN RIVER TOPOGRAPHY.

Looking North from Mt. Pisgah, Miller lease, Winlock Bend. Barren River is close on both sides of this hill. Views show Waller well and bend in Barren River, right center, the quarry ledge in the Gasper oolite, and cypress sandstone capping the ridge, 40 feet above quarry ledge.

of Lost River and a short distance north of Memphis Junction, and in the Roundtree-Covington-Bailey area east and southeast of Memphis Junction. In August the Whittaker shallow pool, just south of the Dixie Highway and about six miles southwest of Bowling Green, was opened with a gusher. Later other shallow wells were drilled in the vicinity and west toward Rockfield. It was also in August that the initial well at the western city limits of Bowling Green was completed on the Briggs lease and started a town lot drilling campaign. The latest shallow sand well of importance and which may open a new pool, was drilled in November, 1920, on the Jefferson lease on the Morgantown Pike where the pike crosses the first ridge west of Bowling Green. The deep sand drilling up to the end of 1920 had at least partly outlined the area of favorable sand condition and had shown several well-defined pools.

Topography.

Warren County may be divided into two topographic provinces, the larger being the plateau area which extends from

the east side of the county westward to the escarpment ridge, about four miles west of Bowling Green. This escarpment extends across the county in a general northeast-southwest direction and is a part of the series of ridges so plainly visible from the L. & N. R. R. from Elizabethtown to Russellville. The

A BARREN RIVER PANORAMA.
Looking west down Winlock Bend from Mt. Pisgah, Miller lease. Davenport Dome at lower end of bend. Escarpment ridge shown in distance.

plateau area is developed on the St. Louis and Ste. Genevieve limestones and is a rolling country deeply incised by the two main streams, Barren River which crosses the central part of the county in a general northwestward flow, and Drakes Creek, its principal tributary, which flows north through the east central part of the county. These streams have very meandering courses and have developed wide bottom-land areas in their many bends. The drainage of most of the remaining area of the plateau is underground, and the surface is marked by many sinkholes. The average elevation of the plateau is between 500 and 600 feet above sea-level.

The second topographic province is the highland area which occupies the northwestern part of the county and covers about one-third the area that the plateau country does. The high-

land area is developed chiefly on the Gasper limestone and Cypress sandstone and is from 200 to 250 feet above the plateau. It is deeply dissected by the drainage, Green River

A GOOD SHALLOW WELL.
Scott No. 1, White Oil Corporation. Flowing and pumping. On Scott Dome, Davenport Section.

on the northern edge of the county, and Barren River and its chief tributary, Gasper River, the latter flowing north along the west side of the county. The east side of the highland area is marked by the line of hills west of Bowling Green. The highest points are close to 800 feet and the lowest points along Barren River about 400 feet above sea-level. The country is very rough on account of the sudden relief from stream valley to hilltop.

Geology.

The geology of Warren County which we must consider extends from the Niagaran limestone of the Silurian to the Cypress sandstone of the Chester although the surficial geology is confined between the upper ledges of the Fort Payne of lower Mississippian age to the lower beds of the Pennsylvanian or Coal Measures.

Some deep tests for oil have penetrated the Ordovician limestone for probably as much as 600 feet or more in search of an equivalent of the Trenton oil formation of Ohio-Indiana. The well logs show prevailing limestones in the Ordovician and some oil is reported in the upper 100 feet of this series. The overlying Silurian, most of which is probably Niagaran, is made up chiefly of limestone with some shale and in places, probably near or at the base, a bed of red rock a few feet thick at the most which some drillers have reported oolitic and closely resembling the Clinton hematitic rock. Bailings from this horizon are red as blood. Some of these Silurian limestone beds are soft and earthy, and some are coarsely crystalline in texture. From well records the writer is inclined to put the thickness of these rocks at about 80 to 100 feet. Between these rocks and the Devonian black shale is about 50 to 55 feet of light gray to brown limestone which is probably Devonian in age and may be referred to the Corniferous limestone, the upper beds of which are the oil sands of northern Allen and eastern Warren counties. (The Corniferous is also the Irvine sand of eastern Kentucky.) At the outcrop of the Devonian limestone in Allen County its thickness is only a few feet, but evidently it thickens materially to the west. Most of the oil in the west half of Warren County is found at depths ranging from 68 to 135 feet below the Black Shale and, therefore, in the writer's opinion, comes from rocks of Silurian age.

The Devonian black shale, which is the key-rock for subsurface structural work, is about 50 feet thick in the eastern part of the county but thickens to about 100 feet in the western part with an average in the oil belt west of Bowling Green between 75 and 90 feet. The variation in thickness over short distances is due to an unconformity with the overlying Mississippian and, therefore, structural work should preferably be based on the lower contact of the shale, unless the thickness of the shale shows reasonable uniformity over the area to be mapped.

A DRILLERS' AND TOOLDRESSERS' CAMP.
Camp on Glen Lilly Pike west of Bowling Green and near Morris pool. These are oil field workers' homes.

The basal Mississippian formation in Warren County is the New Providence shale, which may be as much as 30 or 40 feet thick in the eastern part. At or near the top is a horizon probably the equivalent of the Beaver sand of Wayne County, Kentucky, a few wells of high grade oil have been struck. The oldest exposed formation in the county is the Fort Payne the upper ledges of which outcrop along Barren River in the extreme eastern part of the county. What is exposed here and in Allen County is largely chert, but presumably in unweathered or primary condition it is a silicious limestone for it is reported in well records as lime and sandy lime. This with the overlying Warsaw formation, which is chiefly fossiliferous limestone with some shale, the latter usually at the top, are about 220 feet thick in eastern Warren County, but these two formations must thicken, probably largely the Fort Payne, in going westward, for in the deep pool area west of Bowling Green, from a study of well logs, there is an interval of 330 to 340 feet from what is probably the basal part of the St. Louis to the top of the Black Shale. This would include the New Providence, if present.

The St. Louis limestone is the next younger formation and may be unconformable with the underlying Warsaw, a relation that is suggested by absence of the Spergen limestone and cross-bedding and coarse-grained layers in the basal part of the formation. The St. Louis is a dense blue to gray limestone evidently very silicious in many horizons as weathering produces large quantities of chert. The formation can be recognized by the coral Lithostrotion basaltiforme which is scattered over the surface as chert pieces and which is diag-

OIL DEVELOPMENT IN BOWLING GREEN.
Little Briggs oil pool at west edge of Bowling Green. View looking east from tank house on Briggs lease.

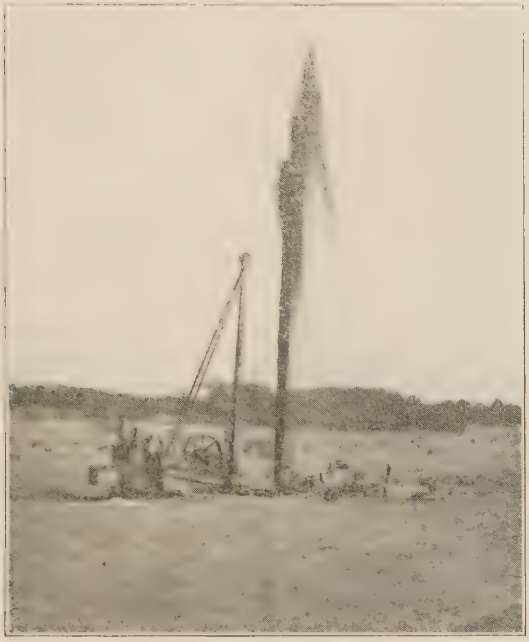
nostic of the St. Louis. The plateau area and sink-hole topography of the county are developed on the St. Louis and overlying Ste. Genevieve formations. There is some question from what formation the gusher shallow wells of Warren County come, but it is the opinion of the writer that the lower or even basal limestone beds of the St. Louis are the oil sand. A fragment of Lithostrotion basaltiforme was recognized in a piece of rock shot from one shallow well,[1] and the writer was given two pieces of water-worn fragments of chert

[1] Written communication from Wilbur Nelson, State Geologist of Tennessee.

which were drilled from two wells in widely separated localities. From drill records the writer puts the thickness of the St. Louis, considering the oil horizon to be basal, at 335 to 350 feet.

The Ste. Genevieve, which includes the Fredonia member, and the Gasper may be considered together for lithologically they are hard to separate as both are light colored limestones, and both are oolitic. The general absence of chert and Lithostrotion basaltiforme identifies them from the St. Louis. No unconformity was found at the base of the Ste. Genevieve in Warren County, but a basal conglomerate does exist at a few places far removed from this area. The absence in Warren County of the O'Hara member of the Ste. Genevieve and the Bethel sandstone, which appears in Todd County to the southwest, may or may not denote a stratigraphic break at the base of the Gasper. From a study of well logs the thickness of the Gasper and Ste. Genevieve must be between 390 and 400 feet. This seems excessive and the writer can offer no data to explain this thickness.

The Cypress sandstone overlies the Gasper. The basal bed exposed along the escarpment ridge four miles west of Bowling Green is a yellow to gray shale from five to seven feet thick above which is cross-bedded sandstone. There may be an unconformity at the base of the Cypress as the depths of some wells not far apart from the top of the Gasper to the top of the Black Shale show considerable differences, but it must be borne in mind that there are other breaks in the stratigraphic column which might account for these differences. A few records along the escarpment ridge are given to show this relation. At the gap on the Morgantown Pike, Jefferson lease, the calculated interval from the base of the Cypress to the top of the Black Shale is about 1,086 feet. On Salt Lick Creek one mile to the northwest the interval is about 1,073 feet. On the ridge less than a half mile north of the Morgantown Pike the interval is about 1,066 feet. At the Brownfield wells, southwest of the Davenport, the interval from two wells is 1,085 feet. On the Barren River Pike west



SHOOTING MOYER No. 1.
This well is located on the Glen Lilly Pike 3 miles west of Bowling Green.

of the Davenport the logs of two wells a half mile apart show the interval to be 1,091 and 1,092 feet.

In the northwestern corner of the county a few thin Chester formations above the Cypress come in, above which lies unconformably the Pennsylvania sandstone and conglomerate.

Structure.

The general structure of Warren County is a north-westward dipping monocline, the average dip being 30 to 40 feet to the mile. This regularity is broken by several uplift areas which extend in a general direction normal to the monoclinal dip. These cause reversals of dip to the southeast and increases the northwest dip in many localities. There are also a few low folds which parallel the northwest dip of the rocks and produce domes and terraces.

There is evidently an uplift extending northeast-southwest along part of the eastern side of the county for along Bays Fork and Barren River there is a series of domes, the domes occupying many of the bends in the streams mentioned, the more prominent being at Cornwall Ford, Sledge pool, Britts Mill, Evans Bend, Jewell Bend, and Moulder pool. Drakes Creek follows another line of uplift as many of the bends are structural. West of Bowling Green is probably the most discernible series of folds in the county, the uplift paralleling the escarpment ridge. How far it extends to the northeast and to the southwest the writer has not determined, but there is no reason why it should not extend across the county. Smaller paralleling folds lie a little southeast of the major fold which is at the base of the range of hills. On the western side of the county Gasper River in part follows an uplift for well-defined domes occupy many of the river bends. Between the escarpment ridge to the east and Gasper River, the area has a very uniform monoclinal dip which is broken by terracing in a few localities.

An area of uplift extending from Bays Fork to Hardcastle paralleling Barren River is suggested by the series of small wells included in the Claypool, Green Hill, and Hardcastle districts. The large area north of Barren River and east of the escarpment ridge has, probably, a uniform dip as no structural irregularities of prominence were observed. The same may be said of the area in the southern part of the county lying between Drakes Creek and the Memphis Branch of the L. & N. R. R. An interesting feature in the geology is the relation of the structure to the main drainage and to the topography in the western part of the county. Nearly all of the prominent bends in Barren River and its three main tributaries are structural. The domes and terraces in the highland area are strongly reflected in the topography.

Occurrence of the Oil.

Oil has been found at eight or nine different horizons in the geologic section that has been drilled through in Warren County, six having proven commercial. For brevity the six

may be grouped into four so as to make formational units. These oil sands are the basal St. Louis in which the gusher wells in the Bowling Green area are found; the Beaver sand which occurs in the New Providence above the Black Shale in the eastern part of the county and from which the amber oil is produced; the Devonian lime sand with its two pays, the first a few feet below the Black Shale, the second about 45 feet below, the Devonian being the big producer in the eastern part of the county; and the Silurian, probably all Niagaran, lime sand with its oil horizons at 68 to 130 feet below the Black Shale, and being the consistent deep producer west of Bowling Green. A detailed description of the commercial sands is given below.

JOHNSON No. 1 SHOT.
Shooting Johnson No. 1. This well is located in the Davenport section.

St. Louis sand. The sand which produces the gusher wells of the Bowling Green district is thought by the writer to be at or near the base of the St. Louis limestone, the oil probably

coming from the lower 20 or 30 feet. The lower beds of this formation can be studied at their outcrop in the eastern part of the county as well as in Allen County. They lie immediately upon a persistent and easily recognized calcareous shale bed about 20 feet thick of the Warsaw formation and are in many places cross-bedded and coarse-grained in texture. In the eastern pools of the county, the basal St. Louis is about 250 feet above the top of the Devonian black shale. In the Bailey shallow oil pool five miles south from Bowling Green along the L. & N. R. R., the shallow oil is between 325 and 335 feet above the Black Shale. These wells start in the Ste. Genevieve oolitic limestone just above the top of the St. Louis cherty limestone. The shallow oil is found at depths from 340 to 360 feet. Farther northwest, or down the dip, in the Davenport section the interval between the shallow oil and the top of the Black Shale is 340 to 350 feet. This shows a thickening of the Mississippian formations below the St. Louis in going northwest toward the Central Coal Basin of western Kentucky. The St. Louis sand is a dark granular and well crystallized limestone. When drilled up it looks like dark carbonaceous sand but when larger fragments are bailed out it is seen to be crystalline and to contain many fragmentary fossil shells and is soft enough to be crushed between the fingers. Most of it will dissolve in acid and any residue is chiefly amorphous silica. This dark limestone may have a considerable thickness in some localities and intercalated with it are thin black to brown shale lenses. Fragments of fossils are abundant and in two localities pieces of water-worn chert, which the writer saw, were said to come from the oil sand.

The basal St. Louis oil sand is not persistent laterally for offsets to good wells may not find any oil and in many cases no water either. The writer suggests, therefore, that the basal beds where productive may occupy shallow erosional depressions in the underlying formation, or sink holes, which may have formed in the soluble Warsaw limestone during the interformational epoch, and that the black shale lenses may be confined to areas where these depressions existed at the time

THE OCCASIONAL STANDARD RIG.

This standard rig on Davenport 3 miles west of Bowling Green on Barren River Pike is the exception rather than the rule in the Warren County Fields. The topography of the Plateau area in this oil field is well shown in this view.

of basal St. Louis deposition. Satisfactory records are not available nor was the writer able to examine the cuttings from enough wells to verify the presence or absence of these thin shale beds in the wells which produced or did not produce oil from this sand. The presence of soft carbonaceous limestone, and in many wells studied carbonaceous black shale, coarsely crystalline limestone, abundant fossil fragments, probable water-worn chert fragments, and irregularity in areal distribution of the oil horizon, suggest basal sedimentation.

The St. Louis sand contains gas, oil, and salt water all of which are under great pressure in the big producing wells. The pressure is soon relieved, however, and the decline in production is very rapid, especially after several wells are drilled in the same locality. Seibert No. 1 at a depth of 423 feet is claimed to have flowed 2,500 barrels of oil the first 24 hours. Whittaker No. 1 which burned for several days after blowing in at a depth of 479 feet is said to have produced 1,500 barrels the first day after the fire was extinguished. This was on August 14 and on November 30, 1920, was still pumping 50

barrels per day. Whittaker No. 5 at 473 feet gauged 1,400 barrels the first 24 hours and after seven weeks was pumping 50 barrels per day. Tarrants No. 1 at 453 feet, the first big St. Louis well to be drilled in Warren County, completed early in May, 1920, produced over $50,000.00 worth of high grade oil in the first few months, and No. 3, same lease, has produced even more than this, but over a longer period. Many wells from 400 to 450 feet in the Davenport section have produced initially from 100 to 500 barrels and are now pumping, December 31, 1920, from 10 to 25 barrels at ages from three to six months. These are illustrations of a few wells that have held up better than the average. Some wells have come in flowing salt water, others have pumped salt water for a few hours or days and come on to oil. Each pool or unit in a pool has just so much fluid in it, evidently, and a well pumping salt water from a location down the dip from a producing oil well may draw the oil from the producing well, the former changing from water to oil. Shooting a well may ruin an offsetting producer, and in other cases dry holes may be drilled surrounding a producer. These facts show the spotted distribution of the St. Louis oil sand.

The oil and gas are probably indigenous to the basal beds of the St. Louis and come from the carbonaceous shale and the organisms, the fossil remains of which we now find in the limestone. The salt water is fossil sea water and is confined to the depression areas in which the basal oil horizon was deposited. The oil and gas have not migrated far from the points of origin and have arranged themselves, as far as pent up gas pressure would allow, according to their respective specific gravities in the small pools or units of a larger pool.

The accumulation of oil into pools in the St. Louis sand is only indirectly controlled by the structure of the rocks as the determining factor is the presence or absence of the basal oil horizon and this is dependent upon the sedimentary conditions that obtained at the beginning of St. Louis time. Where the basal oil horizon underlies a considerable area, structure has an influence on the accumulation and pools may coincide with

TYPE OF PORTABLE RIG.
Drilling on the Mercer lease, National Exploration Company, 4 miles west of Bowling Green. Shows 28 Star Steam drilling rig.

the top of a dome or its flank. However, on many of the most pronounced structures in Warren County the basal St. Louis oil sand is absent.

The largest area or pool of the St. Louis oil is in the Davenport section, between three and four miles northwest of Bowling Green. This area lies along Barren River Pike and in the Seibert and Winlock bends of Barren River. Although many wells are scattered over a large area and there may be a number of wells in a given locality, yet there is much of the territory over which no oil was found in the basal St. Louis beds. For example, one well near the top of the Davenport dome at Thomas Landing is surrounded by wells which produce from the deeper sand but in which no oil was found in the St. Louis sand. Several producing wells in a group, probably low structurally, may have a dry hole in their midst in which the St. Louis sand was absent.

ON THE McGINNIS LEASE.

McGinnis No. 2, Morris Dome. View looking West toward escarpment ridge which is the west flank of the dome. Cedars in foreground are near the top of the dome.

The McGinnis pool, between the Franklin Pike and the railroad at Lost River three miles south of Bowling Green, is located on a well-defined dome, as shown by subsurface studies. A little farther south along the Franklin Pike east of Memphis Junction and extending eastward to the Smallhouse Pike a number of St. Louis wells were drilled with large initial productions, but they declined very rapidly. The Bailey pool

farther south on the same pike was of similar character. Some wells were drilled east from this area in the vicinity of Plano but the writer was unable to make an investigation of this area. It may be assumed, however, that they are of similar character to the Bailey and other close by pools.

The Whittaker pool, which produced some of the largest of the St. Louis wells, is along the Memphis Branch of the L. & N. about midway between Rockfield and Memphis Junction. The pool lies on the flank of a small anticline and is of very limited extent as wells offsetting some of the big producers were dry. A probable extension of this pool lies along a small fold to the southwest toward Rockfield. There are a few shallow wells at the western city limits of Bowling Green interspaced with the deeper wells, and a few scattered ones southeast of the city one of which, the Covington, was the first St. Louis sand well discovered. A well drilled on the Jefferson lease where the Morgantown Pike cuts across the escarpment ridge four miles west of Bowling Green the latter part of November, 1920, and which started at 200 barrels per day may open up another St. Louis sand pool. Its extent, however, will be limited as wells on two sides failed to find this horizon productive.

There seems to be little chance for controversy regarding the origin and accumulation of the oil in the St. Louis sand. The character of the sediments and the localization of the pools point to the origin of the oil being from and the accumulation in the sediments of the basal St. Louis limestone, as there is no connection between the lower oil sands by faulting or fissuring, as far as can be determined by surface observation.

Beaver "sand." The Beaver sand is productive only in the eastern part of the county and is found at the top of the New Providence formation in a lime sand. The oil is very high grade and amber in color and is probably a product from the organic matter which was deposited with the underlying green colored shales. Accumulation is dependent entirely upon the presence or absence of the sand, which is lenticular, and secondarily upon the structure. Some of the wells come in at

100 barrels or better but they soon decline to small production. The only wells producing from this sand at the present time, known to the writer, are in the Sledge pool and at Britts Mill, both on Bays Fork.

Devonian "sand." (*Corniferous*) The Devonian lime sand which underlies the Black Shale is productive principally in the eastern part of the county. There are two pays in the pools of this section and both are thought to be in the Devonian, although the lower may be in the upper ledges of the Silurian limestone. The first pay is the important producer and lies from a few feet to about ten feet below the base of the Black Shale and is from five to ten feet thick. At the present time all the wells in this sand have small production although the first wells in the Sledge and Moulder pools blew in at from 100 to 1,000 barrels. The Moulder wells declined rapidly but the first few wells in the Sledge pool, by pinching them in, held up for some months and produced a great quantity of oil. The pay sand in these pools is brown in color and very porous. The oil was under both gas and salt water pressure, and as the pressure is now relieved the wells are nearly exhausted. There is scattered production along Bays Fork from the Cornwall lease to Britts Mill, the accumulation being on a series of domes. There are a few small wells near Barren River, at Three Forks, and in the Moulder District but the writer has not worked out all of their structural relations as they do not constitute a group of any importance. The Moulder wells which produced so large at the start are located upon a low dome.

The section extending from the Willoughby wells near Bays Fork northwestward to Hardcastle, and taking in the wells of the Williams-Motley, Green Hill, and Hardcastle areas, contains many small wells many of which are on the pump. Sand conditions are not very good, the rock being close-grained, and there appears to be no free circulation of the oil and little if any salt water in the oil formation. The smallness of the wells is probably due largely to the non-porous character of the rock. The writer has made no study of the

A DAVENPORT POOL WELL.
Completion of shallow well in St. Louis sand on Davenport lease, Big Jack Oil Co. on bank of Barren River. It flowed over top of the mast. Depth between 400 and 450 feet. Type of drilling rig used.

structural occurrence of the oil in this section but it is his opinion that structure would exert but a small influence in the accumulation of the oil. On the north side of Barren River on the Gott lease there are a few small wells which probably get the oil in the lower part of the Devonian limestone. The wells are located on the north flank of a dome but the accumulation is probably due largely to an area of local porosity in the rock. Some salt water is also found here lower in the Silurian rocks.

As far as the writer knows there is but one commercial well in the field west of Bowling Green that is producing from

the Devonian. This well was brought in the middle of December, 1920, and is producing from a ten foot pay which is 36 feet below the base of the Black Shale. The structure is a terrace on the monocline northwest of the escarpment ridge Many other wells producing from the Niagaran sand have reported a showing of oil at this horizon.

In Simpson County just south of the Warren line and on the Franklin Pike, the Mitchell wells are in the Devonian about 25 feet below the base of the Black Shale.

Silurian "sand." (*Niagaran*). The Niagaran sands are the present big producers in Warren County. The second pay in some of the wells in the eastern part of the county may be in the Niagaran and the pay in the Beatty District two miles west of Three Forks on the Porter Pike is in the Niagaran limestone 90 feet below the Black Shale. In the western part of the county the pay may be 68 to 130 feet below the Black Shale, two pays probably being represented in this interval but they will be discussed together. The color of the pay sand is light or dark gray and the rock is soft and either earthy in appearance or crystalline, and contains very little grit.

The Niagaran limestone is apparently non-productive over the larger part of Warren County. The three-fourths of the county lying east of the Richardsville Pike, which runs north from Bowling Green, and south and east of the Russellville Pike, which runs southwest from Bowling Green, has been scatteredly drilled and although showings of oil have been found in many wells, the rock has generally been tight and dry. Within the area included in the boundaries given, occupying the western part of the county, the extreme eastern part is underlain by good sand conditions. The western and northern parts are largely unproven although a number of wells were drilled which showed unfavorable sand conditions for oil accumulation in commercial quantities. The real area of production is small. Taking the western edge of Bowling Green as the apex the producing area extends out fan-shaped covering an arc of about 125 degrees. The limit of the fan is but

a short distance beyond the escarpment ridge, approximately four miles from the apex, but it may be extended a little farther. Within this fan area of production there are a number of non-productive sections where either the rock structure is too low or the sand condition is poor. Most of the producing wells are located on the tops and along the flanks of the anticlines and domes. In the saddles and in the synclines the sand condition is generally poor, and little if any oil is found and rarely salt water to amount to anything.

THE SPECTACULAR TARRANTS LEASE.

Tarrants No. 1, first shallow St. Louis sand well west of Bowling Green. This well produced over $50,000.00 in oil in the first few months. Depth of well is 453 feet.

The most pronounced line of structures, and upon which some of the best wells in the district are located, extends along the base of the escarpment ridge from the Morgantown Pike to the north side of Barren River.[2] The Niagaran sand is uniformly porous under this anticline which includes the Briggs dome, just north of the Morgantown Pike; the Morris dome, just north of the Glen Lilly Pike; the Scott dome; and the Davenport dome, at Thomas Landing on Barren River

[2]This anticline was first mentioned by Shaw & Mather in Bulletin 688, page 114, of the U. S. Geological Survey several years before it was drilled.

Pike; and across the river the domes in Winlock Bend. Distinct saddles separate each of these domes. Paralleling this anticline and lying to the east of it are other anticlines, on one of which the Little Briggs pool at the city limits is located.

The Davenport dome, which has been drilled extensively and on which the writer has accurate records, has a 40 foot closure. The surface elevation near the river at well No. 15 is 444 feet above sea-level, and the depth to the top of the sand is 960 feet, bottom 967, and the base of the oil is, therefore, 523 feet below sea-level. The pay is from six to 20 feet thick in this section and very little salt water is found in the oil formation. This water is under no pressure and is evidently not bottom water but occurs directly in the pay. Adjoining wells may show no water at all. These features will be discussed fully under origin.

The top of the Niagaran sand in the wells west of Bowling Green is between 68 and 115 feet below the base of the Black Shale. This range undoubtedly covers more than one horizon, although the color and texture of the pays are quite similar. In the Little Briggs pool at the western outskirts of Bowling Green the pay is usually found at 80 to 90 feet below the Black Shale but in a few wells where this sand was missed oil was found at 183 feet under the Shale. The pool is on a plunging anticline and many of the wells are of small capacity although a few are much larger than the average size well of the county. One well six months old is said to be pumping 40 to 50 barrels. The average depth is under 900 feet but in a few wells where drilling has gone to the deeper pay the depth is nearly 1,000 feet. Farther west in the Davenport section the wells vary in depth from about 950 feet in the vicinity of the river, where the surface elevation is close to 450 feet above sea-level, to 1,100 feet in the valleys leading to the river and in which the surface is not rugged. There is a progressive deepening in going westward, and on top of the escarpment ridge the depths of wells are 1,300 feet and over.

On the Davenport dome, the top of which is at Thomas Landing on Barren River, the top of the pay sand on the Big Jack lease is 85 to 90 feet below the shale. To the west on the flank of the dome the top of the pay in Johnson No. 1 is 89 feet below the shale and in No. 3, 500 feet distant, the top is only 74 feet below the shale. Riggs Davenport No. 1 in Winlock Bend has pay at 75 feet under and on east at the Waller well the pay is 80 feet under the Shale. In the Morris pool, end of the Glen Lilly Pike, the top of the pay varies considerably. Morris No. 1 has a small pay at 40 feet under which is Devonian, but the best pay is at 68 feet under the Shale. In No. 3, two locations distant, the top of the pay is 82 feet under and one location farther 83 feet under. In the Briggs pool, on the Morgantown Pike, the pay is 112 to 115 feet below the Shale. These few figures will give a general idea of the variation in the position of the pay sand over very short distances. The thickness of the pay likewise varies over short distances, it varying between four and 21 feet.

Salt water was encountered in a few wells in the producing territory but the amount is negligible and may not be found in offset wells. Its occurrence may be in wells located high upon a dome and yet it may be entirely absent in wells lower on the same structure. It is, therefore, in pockets and not in a regular salt sand. In Rays Valley, outside of the present producing area, one well is pumping considerable salt water at 117 feet below the Shale and another encountered a larger quantity at 135 feet below. However, there are enough tests around the present producing area to indicate that there is no quantity of salt water behind the oil.

Source of the Oil.

A full discussion of the source of the oil in the Devonian and Silurian sands is not pertinent to this brief resume of the oil pools in Warren County, therefore this point will be only briefly considered.

The oil is either indigenous to the Devonian and Silurian limestones and probably to the sand horizons themselves, or the oil has migrated from the overlying Devonian black shales

to the sands below. The presence of a porous bed in the limestone is the all important factor in the accumulation of the oil although other factors may offset the presence of this requisite. Therefore, drilling may disclose a porous bed in the limestone which may or may not contain oil. On the other hand wells may be drilled on good structures and no oil or salt water found because the rock is tight although fossils, which are evidence of pre-existent organic life, are found in what should be the oil pay, or adjacent to it. Again, wells drilled on favorable structures may find amply porous rock but be barren of oil or water. Salt water is found in quantity in the pools of Allen County and in the eastern side of Warren County but little or no salt water is found in the Devonian or Silurian sands in other parts of the county.

FIRST WELL IN DAVENPORT POOL.

Davenport No. 1 discovery well of the oil fields west of Bowling Green, and C. G. Davenport himself, royalty owner and father of the Davenport oil district. Ridge in the distance is the Northwest flank of the dome.

The presence of porosity in the limestone is due to different causes. The extreme eastern part of Warren County and much of Allen County are in an area where the porosity of the limestone is due to the solvent action of meteoric water which has entered at the outcrop of the limestone and has

slowly percolated through the rock, dissolving the more soluble parts of the limestone and the saline residue on its travels down the dip of the strata. The distance from the outcrop to which this action has been effective is a function of the length of time the outcrop of these beds has been exposed to meteoric water. At the limit of the altered area there must be a large accumulation of water which is dammed back by the tight limestone which is yet unaffected by the meteoric water.[3] The writer has regarded for a long time the extreme eastern side of Warren County to be close to the line of separation of the porous area, produced by meteoric water solution, and the nonporous area, and that the water trough must lie along this line. The occurrence of the oil and the great pressure behind it in the Moulder, Sledge, and adjoining areas showed this to be the true condition, and although considerable oil was recovered, the pools declined very rapidly and salt water in small or large quantities, depending upon how much of the original pressure had been relieved, replaced the oil. The oil has evidently migrated from the fine-grained black shales to the underlying porous limestone through channels provided by joint planes and probably through incipient fissures which must be developed in rigid rock in folded areas such as are found in Allen and Warren counties.

The Green Hill-Hardcastle area is out of the zone in which meteoric water has produced porosity in the limestone. Therefore, it is suggested that the porosity may be primary or due to recrystallization or partial dolomitization. Since all of the wells are small with no pressure back of the oil, and with many tight-sand wells all around, the porosity of the rock must be small and the accumulation erratic. Samples of the sand, results of drilling, and performance of the wells check these conclusions closely.

In the producing area west of Bowling Green the Niagaran limestone appears to have ample porosity at the oil horizons

[3] The writer has given a more detailed description of this origin of porosity in his paper on the "Irvine Oil District, Kentucky" Dept. of Geology & Forestry, Resources of Kentucky, Series V, Vol. 1, No. 2, July, 1919; and Bulletin 151, July, 1919, American Institute of Mining Engineers.

to allow large accumulations. The writer has no evidence at the present time, that the porosity is the result of secondary processes. On account of the earthy texture of much of the producing sand the porosity may be due to primary depositional conditions, although the crystallinity of some of the oil sand suggests secondary action. If the sand porosity is the result of favorable depositional conditions during this stage of Silurian sedimentation, either these special conditions were very local, for to the south, the east, the north, and a few miles west (the western limit of the field is not yet fully determined) the Silurian limestone does not contain oil in commercial quantities, or the absence of oil in the same limestone, which underlies the barren area surrounding the producing field, is due to some condition which has prevented migration from the overlying Black Shale, provided the source of the oil is the Black Shale. Many wells barren of oil or salt water have gone through porous beds in the Niagaran limestone. There was probably ample fauna in the limestone from which the oil could originate, and if the limestone is the source of the oil there appears to be no reason why the pools are not more generally distributed throughout the county and region. Also, since there is no hydraulic pressure in the oil horizons if the oil was formed within the limestone there is no possibility of migration and therefore no reason for accumulation on the higher structural points. Yet the best wells in the Niagaran sands conform closely to the structures. As noted before, wells on the structures usually find good sand conditions; many wells close by in the saddle and synclines have poor sand conditions generally. May there not, therefore, be some peculiar relation between structure and sand condition and localization of oil accumulation? The writer wishes to express the following thought as a possible explanation of the origin and accumulation of the oil in the sands underlying and within a reasonable depth beneath the Black Shale.

The folding which parallels roughly the escarpment ridge, the division between the plateau and the highland areas, was probably more acute than in any other part of this general

district and produced a series of paralleling domes with interdomal saddles and synclines. The folding is less intense as the distance increases from the escarpment ridge. Jointing in the rocks show a general northeast-southwest and lesser northwest-southeast direction, a phenomenon which shows the axes of stress and strain. This pronounced folding very probably produced similar jointing and probably some fissuring of the hard limestone beds which underlie the Black Shale. Through such channels there would be a direct connection between the petroliferous black shales and water-saturated limestone beds below. (The less dense limestones are evidently saturated for shooting frequently brings in some salt water which can be quickly pumped out. There is, however, no hydraulic pressure behind the water.) The oil would pass from the denser and finer grained shale to the more porous water-saturated limestone bed on account of the difference in the capillary pressures of oil and water (a phenomenon of surface tension). The interchange would progress to the point where equilibrium was established, at which time no further migration of the oil could take place either downward or a return upward. Deposition from the ascending water might close many of the channels of migration even before equilibrium was established. Naturally there were some beds in the limestone which were more porous than others and, therefore, contained more water, and to these more porous beds the oil would have the greater tendency to migrate. The oil may have had some chemical effect upon the sand and given it the earthy texture which can be recognized in the cuttings from many wells. So the porosity and general appearance of the oil sand may not be due entirely to depositional conditions but may be, more or less, due to secondary action from the oil content.

The areas of jointing and even fissuring would be most pronounced where the folding was the severest. These areas would, therefore, coincide with the domes and anticlines, and the saddles and synclines would be affected to a much less extent, and probably in many cases not at all. Therefore, the

migration of the oil from the Black Shale to the sand would take place primarily on the structures and to a lesser extent on the flanks or in the saddles or synclines. Likewise, there would be less chance for accumulation of oil in paying quantities the farther away from the line of major structural disturbance, which apparently was near the foot of the escarpment ridge, because of a decrease in the amount of jointing and fissuring. The oil primarily accumulating on the structures would remain there for the water in the saturated porous beds would prevent the oil moving down the dip by gravity.

Some wells were drilled on promising-looking structures and porous rock was found at the horizon which is producing at no great distance away. The absence of oil in these wells may be due to a lack of fissuring or jointing which extended from the shale to the sand. In other words, the area did not receive enough stress during the formation of the fold to create the requisite jointing or fissuring. Many other wells drilled on good structures have failed to find any porous beds in the limestone underlying the Black Shale. The absence of either the channels for migration or a porous, water-saturated bed would prevent accumulation in commercial quantities.

Although the above thoughts are in the rough and may need amplification, it may be readily seen that the following facts can be explained by this theory. Localization of the producing area; presence of the oil on domes and anticlines without water pressure behind it (a modification of the present general interpretation of the anticlinal theory); absence of oil in favorable structures which are underlain by porous strata below the Black Shale; absence of oil under so large a part of Warren County but under which the same fossiliferous Devonian and Silurian limestones and petroliferous black shale extend. It would be hard to explain any of these four primary facts by the theory that postulates that the oil is indigenous to the limestone in which the accumulation has taken place, although there are some arguments which can be advanced in its favor.

In a few places a little oil has been found in a sand lower than the Niagaran. The writer has no detailed records of the performances of these wells except that the well on the Thomas Covington lease south of Bowling Green at 250 feet below the Black Shale was said to have pumped five barrels per day for a while. The sand is very probably in the upper part of the Ordovician. A few wells in the Little Briggs pool just west of Bowling Green have found some oil probably in the Ordovician at 183 feet below the Black Shale.

Extension of the Field.

The object of any geologic study of an oil field is to determine such facts that will be of value in extending the area of production and minimizing the expense of doing so; in increasing the production of the wells; and in conserving the resources of the field by preventing waste of the oil produced and waste of money, time, and energy in the development of the field. From such a preliminary study as the writer has made probably the only valuable objective reached, aside from acquainting the public with the general geologic and economic conditions of the field, is the framing of some theory which may point out the areas which should be tested in an endeavor to extend the field and to call attention to the much larger area which should be but sparsely drilled. With no definite views on the probable origin and accumulation of the oil many geologists would recommend the drilling of all domes and terraces for these structures prevail where the oil pools are located. But many similar structures have been drilled without success and there must be reasons for such results.

Accepting, if you will, the theory of origin and accumulation as outlined by the writer, an endeavor to extend production should be along the line of intensest folding which is probably close to the escarpment ridge, and domes should be selected along this line for initial tests. The writer has not traced this line of folding to the northeast and only for a short distance to the southwest, but it seems reasonable to believe that the folding should extend for some distance both ways from the Bowling Green field. But how far favorable

sand conditions extend from the producing area cannot be told except by drilling. If a working theory of the origin of the porosity in the Niagaran limestone could be advanced, a prediction as to the extension or limits of the field might be made, as was done in the "Irvine Oil District, Kentucky."[4]

The above remarks on the probable extension of the field west of Bowling Green applies only to the sands which underlie the Black Shale, namely the Silurian. The St. Louis oil horizon is different and the possibilities of finding new pools in this sand were outlined earlier in this report.

Economic Considerations.

Should some writer give a good general description of economic conditions in an oil boom community, it would only be necessary to change names in order to apply the stereotype form to all boom localities for practically the same basic conditions prevail, exaggeration and inflation. Warren County has passed through such a period, the peak of inflation having passed in the late summer and early fall of 1920. Very few who bought on the wave of inflation will make any profit from their investments and many will not even get their money back.

The Moulder pool started inflation in that part of the county and in adjoining counties and only those who passed their purchases on to others while the boom was yet on made anything from their investments. A similar condition obtained in the Sledge district, although more oil was run through the pipe line and the early comers who drilled and got production were successful, more or less. The buyers of the much larger area which was purchased at inflated prices and which has proven barren of oil can only write off their losses, and some of the purchasers of production must realize that they hold the sack. No such inflation was reached in other parts of eastern Warren County although leases changed hands many times at prices infinitely greater than their intrinsic value, as they had no oil value whatever.

[4] op. cit.

In the western part of Warren County there were two causes of inflation, the deep sand below the Shale and the shallow gusher sand, the latter probably having the greater effect upon inflation. Wells blowing in at several hundred to a thousand barrels per day at a depth of only 450 feet, on an average, with the possibility of the deeper sands undetermined caused acreage everywhere in the boom area to sell at very high figures. Although the shallow sand wells do not hold up long, many made money from their investments but many more were far less fortunate, for the shallow sand is very spotted and in some localities the well that came in so big was gone almost as quick. In many areas deepening of the wells to the Niagaran sand resulted in additional loss as oil from that horizon is restricted to certain areas. In the areas south of Bowling Green the life of the shallow wells is short, but in the Davenport section and in the Whittaker pool some of the wells have held up very good considering their depth and the character of formation from which the oil comes. Drilling for the shallow St. Louis oil can never be considered on a business basis as it is purely a gamble.

In drilling for the Niagaran oil a consideration of economic factors are pertinent. If any estimate can be made before drilling from geologic structure or from prevailing sand condition, regarding the probable size of the well, then by computing the cost of the completed well an estimate can be made as to how long it will require for the production to pay for the cost of the well and the acreage that well will drain.[1] A well 1,000 feet deep will cost, at the present price of drilling and supplies, between $6,000.00 and $6,500.00 on the pump; a well 1,300 feet deep, which would be on the hills in the highland area, will cost over $8,000.00 on the pump. The oil west of Bowling Green is over 38 degrees Baume gravity which classifies it as Somerset Light for which is paid in the field $4.18 (market price $4.50 less 32c pipe line charge). At these figures a well must have an average daily production of eight barrels, pumping 25 days per month, to pay the royalty, a moderate overhead expense, and the actual cost of a 1,000 foot well

in nine months' time; for the 1,300 foot well it would require twelve months. A well to average eight barrel per day for a year must come in flush several times this amount, in this character of sand, and the pay must be more than a few feet thick.[5] It would be most interesting to find out the number of producing wells in the county and divide into the production to determine the average size of all the wells. Some production figures are given at the end of this report but the actual number of wells on properties with pipe line connections is not known. The number on December 31, 1920, however, cannot be less than 200 and probably many more, most of which are in the Bowling Green section. This will include both shallow and deep sand wells.

The field is too young to furnish such data as is necessary in the construction of decline and future production curves. Enough was said regarding the shallow St. Louis sand to show that the decline of the wells is precipitous. However, from the very nature of the occurrence of these pools nothing of any detailed value could be obtained from production data which would be of any working value for the field as a whole. In the Niagaran sands the decline of wells is more normal. The writer has no figures of his own but was furnished the decline curve on one property in the Davenport section which is well located structurally and under which the sand condition is uniform. These figures showed a decline of approximately 50% in the first nine or ten months of production run through the pipe line, with developments progressing the entire period. The writer is not so optimistic as to believe that all leases will show such a small rate of decline as the example cited.

Warren County is well supplied with pipe line facilities although some of the wells ahead of general development work are not yet reached by any of the carriers. The Indian Refining Co., whose refinery is at Lawrenceville, Illinois, is the

[5] Since the preparation of this report Somerset Light has been reduced three times and is now $3.75, February 1, 1921. The nine and twelve month periods must be revised proportionately for wells drilled during the period this lower price prevails which will probably be for only a few months. On February 4, another cut of 75c brought Somerset Light down to $3.00.

largest pipe line carrier in Warren County. Others are Western Kentucky Pipe Line Producing & Refining Co., American Pipe Line & Refining Co., Petroleum Refining Co., Texas Shell Pipe Line Co., Eastern Gulf Oil Co., and Stoll Oil Refining Co. The oil is run into storage tanks at the loading racks or some other convenient place and shipped by tank cars to the refineries.

There has been talk for the past year and a half of building a refinery at Bowling Green, and several companies have made preliminary plans for such construction, but to date nothing more than buying sites has been done although claim is made that the material for the refinery projected by the Western Kentucky Pipe Line Producing & Refining Co. has been ordered.

There are four oil well supply houses, a few other dealers where oil well supplies can be purchased or ordered, and several tool and machine shops in Bowling Green, ample to supply the needs of the field, if the material is available from the manufacturer. Work has been retarded but not greatly handicapped during the past year by scarcity of supply material.

A large part of the drilling is done by gasoline tractor machines of which the Star, Sparta, Keystone, and Cyclone types, good for depths of from 1,000 to 2,000 feet, depending upon the size of the machine, are the most popular. They are easily moved and quickly rigged up, use fuel that is always available and easily transported, require very little water for drilling, and are comparatively safe from igniting a sudden flow of oil or gas. For most of the deeper wells steam rigs are used, the Star, Parkersburg, and National being the most popular. A few Standard rigs dot the area and add to the picturesqueness of the scene.

From the Green Hill area on the east to the Highland area on the west hard rock roads good the year round serve as the arteries of transportation from Bowling Green, which is the hub of the oil industry of Warren County. The contour of the country east of the Highland area and in which 95% of the development is confined is rolling and the cost of devel-

opment thereby lessened. The climate in general is not severe in either winter or summer and there need be no great curtailment of operations during the winter months.

Most of the development to date was done by the individual operator and small company as there are only a few of the larger organizations operating in Warren County. Development in the deeper areas has already reached the stage, viewed from an economic standpoint, where it is a company proposition.

DETAILED WELL RECORDS

The few well records given below are typical of the different sections in Warren County. Some are detailed logs, others simply show the depths to and through the Devonian Black Shale and the record of the oil sand. The oil analyses cover the various oils found in the county and the pipe line runs show the rate of progress in the development of the industry.

BEN F. HEWITT No. 1. HARDCASTLE DISTRICT.

Red clay	0– 20
Lime, hard	20– 80
" hard, gray	80–180
" soft, gray, sandy (gas)	180–185
" hard, white	185–200
" soft, sandy	200–205
" hard, white	205–345
" sandy, white	345–400
" soft, green (New Providence)	400–440
Shale, black (Devonian)	440–492
Lime, hard, black	492–500
" gray sand	500–503
" sand, hard, white	503–510
" sand, hard, brown	510–522
" hard, gray	522–525
" soft, coarse, gray	525–532
" sand, soft, brown	532–542
" soft, coarse, gray	542–554
" sand, soft, brown	554–563
" total depth	563–568

JOE SHIPLEY No. 1. CEMETERY PIKE, 2 MILES NORTHEAST BOWLING GREEN.

Clay	0– 32
Lime, yellow	32– 38
" white	38– 83
" gray—water	83– 95

Lime, brown—sulphur water at 162	95–239
black sulphur water at 181	
" hard, brown, sandy	239–258
Shale, hard, brown	258–267
Lime, brown	267–310
Soapstone	310–316
Lime, blue	316–333
" blue, (gas at 365)	333–376
" white, sandy (show oil at 384)	376–390
" blue (gas at 408 and 550)	390–638
Shale, black (Devonian)	638–705
Lime, cap	705–709
Sand, white	709–720
Lime and sand, hard, gray	720–742
Lime, sand, brown (show of oil)	742–745
" blue	745–749
" gray and gritty	749–771
" soft, gray	771–775
" soft, blue (show oil at 780)	775–806
" gray and sandy	806–820
" blue total depth	820–839

GRAHAM No. 1, RICHARDSVILLE PIKE, 3 MILES NORTHWEST BOWLING GREEN.

Lime	0– 682
Shale, black (Devonian)	682– 767
Lime, gray	767– 783
" sand, white (oil odor)	783– 795
" sand, brown (oil show)	795– 819
" gray	819– 856
" soft, gray (show)	856– 876
" light gray	876– 902
"	902–1075
"	1075–1086
" sand, brown (oil odor)	1086–1121
" dark	1121–1130
Fresh water 40–60; Sulphur water	210– 225

J. B. SUMPTER No. 1. ONE MILE SOUTH BOWLING GREEN.

Lime, (black sulphur water at 240)	0– 777
Shale, black (Devonian)	777– 837
Lime, brown and gray	837– 932
Red rock	932– 937
Lime, (show oil)	937– 943
Lime, gray and blue	943–1005

C. G. DAVENPORT No. 1. (DR. RIGGS) WINLOCK BEND.

Sandy loam	0– 14
Lime, white (water)	14– 30
Sand, caving	30– 48

Lime, blue	48–	63
Mud cave	63–	66
Lime, gray	66–	91
" white	91–	181
" brown	181–	240
" blue	240–	244
" black	244–	251
" gray	251–	347
" shaley	347–	367
" gray	367–	473
" blue	473–	480
" gray	480–	616
" brown	616–	623
" gray	623–	763
Shale, black (Devonian)	763–	852
Lime, gray	852–	864
" white	864–	876
" brown	876–	904
" gray	904–	927
" gray pay sand	927–	943
" blue	943–	951

J. T. Hunter No. 1. Morgantown Pike, 3 Miles West Bowling Green.

Show oil, St. Louis sand		424
Shale, black (Devonian)	795–	870
Lime, gray, oil and gas	941–	947
Red rock	964–	966

Elrod No. 1, Five Miles South Bowling Green (Bailey Pool District)

Clay and boulders	0–	18
Lime, hard, gray	18–	38
" hard, white (crevice at 129)	38–	134
" blue	134–	138
" white	138–	140
" blue	140–	194
" brown	194–	270
" and sand, hard, white	270–	290
" soft, gray	290–	298
" hard, gray	298–	302
" sand, soft	302–	320
" gray, (probable oil sand)	320–	336
" gray, sandy	336–	365
" brown (probable oil sand)	365–	391
" gray, sandy and black slate	391–	416
" and sand, gray	416–	428
" hard, white	428–	442
" blue, hard	442–	470

Lime, black	470– 485
" soft, black	485– 542
Slate, black	542– 574
Lime, blue	574– 589
" black and hard sand	589– 639
" and sand	639– 654
Shale, brown and sand, hard (Devonian)	654– 677
" black	677– 725
Lime, gray	725– 733
" and sand, brown	733– 745
" and sand, white	745– 769
" brown, sandy	769– 773
" gray	773– 807
" and sand	807– 815
" and sand, brown	815– 835
" gray	835– 863
Shale, black	863– 895
Lime, brown, sandy	895– 899
" black	899– 927
" salt sand (filled in casing)	927– 931

DAVENPORT No. 11, BIG JACK OIL CO. 4 MILES WEST BOWLING GREEN.
Aneroid elevation, 570 feet.

Black Shale	919–1004
Oil sand	1089–1107

DAVENPORT No. 15, BIG JACK OIL CO.
Aneroid elevation, 444 feet.

Black Shale	785– 870
Oil sand	960– 967

WALLER No. 1, HEAD OF WINLOCK BEND, 5 MILES NORTHWEST BOWLING GREEN. Elevation about 460 feet.

Black Shale	755– 845
Lime	845– 925
Oil sand	925– 929

Fresh water at 250 feet.
Salt water at 375 feet.

MORRIS No. 1, GLEN LILLY PIKE, 4 MILES WEST BOWLING GREEN.

Black Shale	855– 938
Oil sand, (Devonian)	978– 982
Oil show	998–1002
Oil sand, (Silurian)	1006–1026

JENNIE BRIGGS No. 2, MORGANTOWN PIKE, 4 MILES WEST BOWLING GREEN.

Black Shale,	968–1065
Oil show, (Devonian)	1102–1112
Oil sand, (Silurian)	1180–1190

Oil filled hole 1,075 feet.

JEFFERSON No. 1, MORGANTOWN PIKE, 4½ MILES WEST BOWLING GREEN.
Aneroid elevation, 570 feet.

Black Shale, (bottom)	– 990
Oil show	–1017
Oil sand	1090–1093
Oil sand	1105–1115
(Bottom hole)	–1136

JEFFERSON No. 2, MORGANTOWN PIKE.
Aneroid elevation, 684 feet.

St. Louis sand	671– 675

MAE PALMER No. 1, 1 MILE NORTHWEST JEFFERSON LEASE, MORGANTOWN PIKE, 5½ MILES WEST BOWLING GREEN.
Aneroid elevation, 580 feet.

Black Shale	928–1015
Oil sand, (Devonian)	1051–1061

J. JOHNSON No. 2, DAVENPORT OIL CO., BARREN RIVER PIKE, 4½ MILES NORTHWEST BOWLING GREEN.
Aneroid elevation, 500 feet.

Black Shale	865– 945
Oil sand	1030–1051

GEORGIA DAVENPORT No. 1, BARREN RIVER PIKE, 5 MILES NORTHWEST BOWLING GREEN.
Aneroid elevation, 721 feet.

Black Shale	1112–1204
Oil sand	1287–1301

BROWNFIELD No. 1, ESCARPMENT RIDGE 5 MILES NORTHWEST BOWLING GREEN. Aneroid elevation, 725 feet.

Black Shale	1076–1156
Oil sand	1260–1271

MANNING No. 1, RAYS VALLEY 6 MILES NORTHWEST BOWLING GREEN.

Black Shale	786– 863
Oil sand	965– 980
Salt sand, (water)	980– 982

BIDDLE No. 1, BROWNS LOCK, BARREN RIVER, 7 MILES NORTHWEST BOWLING GREEN.

Black Shale	945–1045
Oil sand, (Devonian)	1080–1106
Oil sand, (Silurian)	1150–1180
(Bottom hole)	–1206

DAVENPORT, (DR. RIGGS) WINLOCK BEND, BARREN RIVER.
Elevation about 445 feet.

St. Louis sand	407– 415

TARRANTS No. 1, STEIN ET AL. 3 MILES NORTHWEST BOWLING GREEN.

St. Louis sand	450– 453

WHITTAKER No. 1, DIXIE HIGHWAY, 6 MILES SOUTHWEST BOWLING GREEN.

Brown sandy lime	443– 462
Brown lime	462– 478
Oil sand	47?

CLARENCE WILSON, BORRONE No. 1, 3 MILES SOUTH BOWLING GREEN.

Lime, white	0– 14
" blue (water at 110)	14– 250
" white	250– 300
" blue	300– 428
" gray, oil sand	428- 440
" brown, very hard	440– 444
" best oil and salt water	444– 448

DETAILED ANALYSES.

DEVONIAN OIL.

Analysis No. 1.[6]

Laboratory No. G-3861—Petroleum labeled "Lessor (Dr.) Hunter. Lessee, Duplex Oil Co., 3 miles west of Bowling Green, Warren County, Ky. 960 feet, total depth." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity 0.834 at 60° F., equivalent to 37.9° B.

Distilled below 150° C. (302° F.)	20.2% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	32.0% (Burning oil fraction)
Thick, brown tar	45.0%
Loss in analysis	2.8%
	100.0%

The oil began to distill at 65° C. (149° F.).

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

SILURIAN OIL.

Analysis No. 2.[6]

Laboratory No. G-3865—Petroleum labeled "Fresh, green oil, Joe B. Sumpter, No. 1, Mrs. Gray, lessee, ½ mile west of Bowling Green, Warren Co., Ky. Oil at 880-900 ft., total depth, 920 ft. Oil horizon Niagaran. Collected by W. R. Jillson, Sept. 14, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

[6]Analysis Nos.: 1, 2, 3, 4, 5, and 6 from Oil and Gas resources of Kentucky, by W. R. Jillson, first Ed., 1919, third Ed., 1920, pp. 35 and 36.

Analysis.

Specific gravity at 60° F., 0.865, equivalent to 31.9° B.
Distilled below 150° C. (302° F.) ..... 9.3% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 37.5% (Burning oil fraction)
Tarry residue 52.5%
Loss in analysis 0.7%

100.0%

The oil began to distill about 80° C. (176° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

MISSISSIPPIAN OIL.

Analysis No. 3.[7]

Laboratory No. G-3864—Petroleum, labeled "(d) Green oil, Maj. R. W. Covington, No. 1, 355 feet above shale, ½ miles southeast of Bowling Green, Warren Co., Ky. Sept. 15, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity at 60° F., 0.854, equivalent to 33.9° B.
Distilled below 150° C. (302° F.) ..... 13.0% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 36.5% (Burning oil fraction)
Tarry residue 50.0%
Loss in analysis 0.5%

100.0%

The oil began to distill at 75° C. (167° F.).

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

DEVONIAN OIL.

Analysis No. 4.[7]

Laboratory No. G-3863—Petroleum labeled "Green oil, open steel tank. Horace Bohon, No. 1. A. Goldstein, lessee. 840 feet deep. below shale. 1 mile east of Bowling Green, Warren County, Ky. Collected by W. R. Jillson, Sept. 14, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity at 60° F., 0.856, equivalent to 33.6° B.
Distilled below 150° C. (302° F.) ..... 13.0% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 36.5% (Burning oil fraction)
Tarry residue and loss by difference 50.5%

100.0%

[7]Oil and Gas Resources of Kentucky, by W. R. Jillson, first Ed., 1919, third Ed., 1920, pp. 36 and 37.

The oil began to distill at 70° C. (158° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

DEVONIAN—SILURIAN OIL.

Analysis No. 5.[8]

Laboratory No. G—3862—Petroleum labeled "Green oil from J. A. Hamilton & Co., Wayne O'Neil, lessee, ½ mile northeast of Bowling Green, Warren County, Ky. Oil horizon, Onondaga and Niagara limestones. Depth, 850 feet. Collected by W. R. Jillson, September, 14, 1919." Received from W. R. Jillson, State Geologist, September 15, 1919.

Analysis.

Specific gravity at 60° F., 0.856, equivalent to 33.6° B.		
Distilled below 150° C. (302° F.)	14.5%	(Gasoline fraction)
Distilled from 150° to 300° C. (302–572° F.)	34.5%	(Burning oil fraction)
Tarry residue	50.5%	
Loss in analysis	0.5%	
	100.0%	

The oil began to distill at 65° C. (149° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Sept. 19, 1919.)

MISSISSIPPIAN OIL.

Analysis No. 6.

Laboratory No. G-3851—Petroleum labeled "Green Oil, Waverly Stray horizon, above Black Shale, on Drake's Creek, Warren County, Ky. V. Humbrecht, lessee. Depth 115 feet. Collected by W. R. Jillson, Aug. 2, 1919." Sample a rather thin, green oil, dark brown by transmitted light.

Analysis.

Specific gravity by hydrometer at 60° F., 0.840, equivalent to 36.7° B.		
Distilled below 300° F.	20.0%	(Gasoline fraction)
Distilled between 300 and 572° F.	36.5%	(Burning oil fraction)
Residue of thick, brown oil	42.8%	
Loss of distillation	0.7%	
	100.0%	

Percentages by volume.

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

DEVONIAN OIL.

Analysis No. 7.[9]

[8] Oil & Gas Resources of Kentucky, by W. R. Jillson, first Ed., 1919, third Ed., 1920, p. 37.

[9] Analysis Nos.: 7, 8, 9, and 10 from Contributions to Kentucky Geology, by W. R. Jillson, Article XIV, The New Oil and Gas Pools of Warren County, Kentucky, p. 234. 1920.

Laboratory No. G-3888—Petroleum labeled "Green crude oil, Glen Lily Tract, C. L. Goodrum lease. 1 mile west of Bowling Green, Warren County, Ky. Collected by C. H. Scott, Jan. 1, 1920." Sample, thin, green oil, dark brown by transmitted light. Forwarded by W. R. Jillson, State Geologist, for analysis.

Analysis.

Specific gravity, 0.848, equivalent to 35.1° B.		
Distilled below 150° C. (302° F.)	21.5%	(Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.)	33.8%	(Burning oil fraction)
Thick green-brown tar	44.4%	
Loss in analysis	0.3%	
	100.0%	

Began to distill at 55° C. (131° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Lexington, Ky., Feb. 6, 1920.)

MISSISSIPPIAN OIL.

Analysis No. 8.

Laboratory No. G-3879—Petroleum labeled "Fresh natural flow of amber crude oil from the Jim Britt farm—Waverly sand—Warren County, Ky. Collected by W. R. Jillson, State Geologist, November 9, 1919." Sample, a thin, amber colored oil having a strong green fluorescence. When the bottle was uncorked a few small gas bubbles appeared in the liquid (temperature about 80° F.).

Analysis.

Specific gravity, 0.810, equivalent to 44.8° B.		
Distillate below 150° C. (302° F.)	25.0%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	38.8%	(Burning oil fraction)
Pasty, green residue	34.4%	
Loss in analysis	1.8%	
	100.0%	

Began to distill at 40° C. (148° F.)

The residue after distillation still retained the strong, green fluorescence of the original oil. It partly solidified on cooling, apparently from the separation of solid paraffin.

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

MISSISSIPPIAN OIL.

Analysis No. 9.

Laboratory No. G-3880—Petroleum labeled "Fresh pumping olive-green crude oil from Sam Thomas Heirs, Waverly sand, Warren County, Ky. Collected by W. R. Jillson, State Geologist, November 9, 1919." Sample a thin, green oil, dark brown by transmitted light.

Analysis.

Specific gravity, 0.844, equivalent to 35.9° B.
Distillate below 150° C. (302° F.) ..... 20.0% (Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.) 33.8% (Burning oil fraction)
Thick, brown, oily residue 46.2%

100.0%

Began to distill at 68° C. (199° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

MISSISSIPPIAN OIL.

Analysis No. 10.

Laboratory No. G-3881—Petroleum labeled "Fresh natural flowing crude green oil from Albert Covington lease, Warren County, Ky. Waverly sand producing. Collected by W. R. Jillson, State Geologist, Nov. 11, 1919." Sample a pint of thin, green oil, received November 24, 1919.

Analysis.

Specific gravity 0.8815, equivalent to 34.4° B.
Distilled below 150° C. (302° F.) ..... 14.5% (Gasoline fraction)
Distilled from 150° to 300° C. (302-572° F.) 38.5% (Burning oil fraction)
Green and brown, thick residue 46.5%
Loss in analysis 0.5%

100.0%

Began to distill at 70° (158° F.)

ALFRED M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter)

DEVONIAN OIL.

Analysis No. 11.[10]

Laboratory No. G-3875—Petroleum received October 1, 1919, by mail, from the Department of Geology and Forestry, Frankfort, labeled "Green oil from the Z. Moody lease, Hoge Oil & Gas Co., operators, near Green Hill, Warren Co., Ky. Oil horizon, Onondaga. Fresh oil, collected by W. R. Jillson, Sept. 26, 1919." Sample, a thin green oil, dark brown by transmitted light.

[10]A new and heretofore unpublished analysis.

Analysis.

Specific gravity, 0.832, equivalent to 38.3° B.		
Distillate below 150° C. (302° F.)	23.1%	(Gasoline fraction)
Distillate from 150° to 300° C. (302-572° F.)	32.5%	(Burning oil fraction)
Brown tar	41.9%	
Loss in analysis	2.5%	
	100.0%	

A. M. PETER, *Chief Chemist.*

(Analysis by A. M. Peter, Lexington, Ky., October 2, 1919.)

V

A NEW METHOD OF PRODUCING CRUDE OIL IN KENTUCKY.

By Willard Rouse Jillson.
Director and State Geologist.

Within the last year experimental work has been undertaken at Ravenna, Estill County, Kentucky, looking towards the production of crude oil in commercial quantities by an entirely different method than any which has heretofore been used in this State. The process as already developed and projected is probably new, also, for the entire United States, though the Union Oil Co. of California has been experimenting in a somewhat similar way with a tunnel driven into Sulphur Mountain in Ventura County, California.[1] Similar methods have been used in certain parts of Europe, notably Alsace.[2] The Estill County method involved consists of the sinking of a shaft 8 by 12 feet to a depth of 130 feet through the Devonian black (Chattanooga) shale to the underlying oil "sand," the Onondaga (Corniferous) limestone. This work has progressed satisfactorily to date, the shaft having been sunk close to an old producing oil well on the Hudson farm within the confines of Ravenna townsite.

This preliminary work because of its exploratory nature has necessarily been carried on much slower than might otherwise have been expected. Notwithstanding the difficulties attending, however, the shaft has been sunk into the oil "sand," and oil has actually been produced from the Onondaga limestone in quantities that have averaged about two or three barrels a day. This amount of crude oil production does not, of course, justify the expenditure necessary to sink a shaft of the size indicated; but the present production is regarded as only an incident to the development of this property, which was suspended at this

[1]Bulletin of the Union Oil Co. of Calif., Vol. 1, pp. 5-8, Aug., 1921.
[2]M. Paul de Chambrier, Eng. and Mining Jour., Vol. 112, p. 103, July 16, 1921.

STOCKADE ENCLOSING "OIL MINE."
In the foreground is the shaft enclosed by a stockade. On the hill in the background is a small oil tank used in working this "Oil Mine." The fill in the foreground is principally made of Black (Devonian) Shale which was removed in construction of the shaft.

point awaiting the installation of larger machinery. It is further the plan of the operators, Mr. D. W. R. Kinney, George W. Eastom and John McMinn, to drift out into the oil "sand" a triangular tunnel 6 feet high and 7 feet at the base to a distance of one thousand feet in a northeasterly direction from the main shaft. This prospecting tunnel will drive slightly upwards as it goes forward with the result, which is outlined, that oil will be produced into it and find its way by gravity to a sump at the base of the main shaft, where it is proposed to take it out by pumping.

It is the plan of the operators to enlarge the base of the shaft into a room 12 feet square and 7 feet high. It is proposed further to retort on the ground the oil impregnated limestone or "sand" cut from the 1,000-foot tunnel. The oil "sand" it is claimed carries as much as 25% by volume of crude oil. This fraction is regarded as high, although the actual figure is not known. Investigations made in the mining laboratory of the University of Kentucky indicate that this limestone of Devon-

ian age when excavated may contain and produce under proper methods upwards of from between 5 and 10 gallons per short ton. It has been shown that after the firing and retorting the limestone may be used as an excellent fertilizer, and sold it is stated at about $3.00 per ton.

The work of excavation at Ravenna to date has been done by McMinn under the direction of D. W. R. Kinney. It is stated that provisional to a recent reorganization of this operation Frank W. Armstrong and associates of Chicago, Ill., will take up the further development of this property, drive the new experimental tunnel and operate it in close proximity to the main shaft. In conjunction with the retorting of the oil "sand" it is also proposed to retort the Chattanooga black shale (Devonian) which occurs on his property. The productivity of the "oil" shale in this locality has already been made the subject of investigation, the results of which have been published.[1]

The practicality of this method of "oil mining" remains to be proven. The work up to the present has been little more than a novelty experiment, which has shown that oil can be produced from an open shaft. Whether commercial quantities can be produced from an open shaft or from tunnels drifted out into the oil "sand" from this shaft remains to be seen. The feasibility of retorting excavated oil "sand" to recover oil, even with the possibility of using the fired "sand" as a limestone fertilizer in a section of reasonable market, is another experiment. It is recognized that while crude oils produced, even in small quantities, from an oil mine of this character might make the venture a paying one in times of high price crudes, it must also be pointed out that it will be the sluggish or subnormal oil market that this new industry must necessarily be prepared to meet. This will be true of such projects as this, even more so than the oil producing (drilling) industry, because of the larger investment made necessary by the first and the relatively smaller investment made necessary by the latter.

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[1]A Preliminary Report on the Oil Shales of Kentucky, W. R. Jillson, Economic Papers on Ky. Geology, p. 1, Ky. Geol. Survey, Series VI, Vol. II, 1921.

THE KINNEY "OIL MINE" SHAFT.

This property is located in Bayonne, Estill C

DETAIL OF THE ONONDAGA LIMESTONE.

Here are shown in excellent relief the cherty "hornstone" inclusions and the soft shelly (fossiliferous) horizon in the center (see hammer). The thickness of the "Corniferous" at this point near Irvine, Ky., is 10 feet.

As a scientific experiment the Ravenna oil mine is indeed really worth while, and oil men generally will find much interest in going there and in getting down in to the oil "sand." At the base of this experimental shaft it is quite possible to see under what conditions crude oil is produced out of the Onondaga (Corniferous) limestone. Many new notions concerning the porosity of "sands" will be found there waiting the earnest investigator. One of the things which will strike him as of more than ordinary importance is the fact that the oil is produced into the base of the shaft not throughout the entire thickness of the oil "sand," but through a fraction of the entire thickness, and there from crevices or fractures back into "sand." At the present time many rather large blocks of the oil "sand" (limestone) may be taken from the producing strata for experimental

study. It has been found that frequently when such blocks of the "sand" (limestone) are shattered the newly exposed faces will show that because of its compactness, much of the limestone never did contain any oil. While the opening in the "sand" (limestone) today is rather restricted, sufficient surface of the oil producing strata is available to afford rather extended studies. Exposures of the dry gray green and white shales below the black (Chattanooga) shale and above the Onondaga limestone may also be examined sufficiently to convince any one of the fact that the crude oil which is now being produced from the Onondaga limestone below never came down through it from the Devonian black (Chattanooga) shale above.

VI

RETORTING METHODS AS APPLIED TO KENTUCKY OIL SHALES

By Charles Stevens Crouse,
Oil Shale Technologist.

The State of Kentucky has within its borders a hitherto untouched natural resource which in its potentialities is, perhaps, second to none. This potential source of wealth is compassed in the vast deposits of oil shale so abundantly found in various portions of the Commonwealth.

There are three separate and distinct groups of bituminous shales in Kentucky from any or all of which oil may be obtained but, owing to physical character and occurrence, only the lowest group, the Devonian or Black Shale, is considered commercially important at the present time. The next shale above the Devonian is the Sunbury which occurs toward the base of the Waverly (Mississippian) and is very similar to the Devonian and, in this paper, will be considered with it so far as retorting methods and commercial exploitation is concerned. The uppermost group of shales are found in the Pottsville (Pennsylvanian) at various horizons in the Eastern and Western Kentucky Coal Fields and their action when retorted is so different from that of either of the other shales that, for the purposes of this paper, they will not be considered.

Sufficient geologic and other field work has been done to show that there are approximately one thousand square miles of exposed shale available in Kentucky at the present time for immediate investigation and possible commercial operation. The above named acreage is the shale which it will be possible to mine by steam shovel methods and does not take into con-

sideration at all the practically inexhaustible deposits which lie below ground necessitating underground methods of mining for their recovery. Assuming an average shale thickness for this area of fifty feet, which assumption is conservative, and a weight per cubic foot of one hundred and thirty pounds, which is the average of twenty samples from widely separated points in the state, we arrive at the stupendous figure of 90,604,800,000 tons of shale immediately available for exploitation on a commercial scale.

Although no exhaustive sampling of these shales has been done to date, still that which has been done indicates that a recovery of about a half a barrel of crude oil to the ton may be generally expected throughout the shale area. In some places the recovery will be greater and in some less, but the figure quoted should be near an average for the entire deposit. Such being the case, the tonnage given translated into terms of crude oil shows that the shale area is actually an immense reservoir of oil containing something like 45,000,000,000 barrels of crude oil. This immense quantity of oil simply awaits the day when man, through his ingenuity, shall find the key to this vast natural storehouse, and liberate in a commercial way the oil locked up during the geologic ages past. That time, if it has not now come, is rapidly approaching. The purpose of this paper is therefore to describe the various keys that have been so far devised, and to see if one or more of them may not be used successfully.

The retorting problem, then, or, in other words, the production of oil and various by-products from the shale, is the big problem confronting all those who are planning on the working of shale deposits. Moreover, it must be borne in mind that not only is it a question of oil recovery, but also a question of the utilization of all the by-products possible. These by-products include ammonium sulphate, potash, coal tar products, spent shale, and other things not yet dreamed of, that will make the industry so diversified that it will not depend on any one thing for its profits, but on an increasingly larger number of products. In this way alone is there to be

found commercial safety for times of commercial prosperity and depression.

The greater part of the constructive work done in this state in the retorting of Kentucky oil shales has been accomplished by the writer in the Mining Laboratory of the University of Kentucky at Lexington. A great deal of work has been done, however, elsewhere, both by the United States Bureau of Mines and by private individuals with the shales of Colorado, Utah, California, etc., the so called Western Shales. The oil shale industry has been on a commercial basis in Scotland for some seventy odd years. The Western (American) Shales in some vital particulars are, however, quite different from the Kentucky Shales and, although it is stated on good authority that the Kentucky Shales are similar to those of Scotland and that the Scotch method of retorting might, therefore, be used in Kentucky, it still cannot be considered the best method as it now stands. We must for this reason look either to some modification of Scotch practice or to some altogether new procedure to give us the method that we wish.

There is no oil, or very little, in shale as such. That is oil cannot be extracted from shale by means of solvents or pressure. Rather is it in the form of what has been called "kerogen." This "kerogen" consists of particles of organic matter either of animal or vegetable origin or both and, before oil can be obtained, the shale must be heated in order to volatilize or gassify these organic compounds, thus forming various hydro-carbons. Subsequently that portion of the gas which can be condensed, is reduced to a liquid or crude oil. It will thus be seen that, in the first place, the quantity and quality of the oil obtained depends directly on the amount and character of the organic compounds in the shale. However the proposition is not quite so simple as may appear because the gases, after they are formed, are very easily broken up or "cracked" by variation in heat so that, given a certain shale, both the question of quantity and quality of oil obtained is almost entirely a matter of heat control. It follows as a corollary that the amount and sort of oil produced may be varied

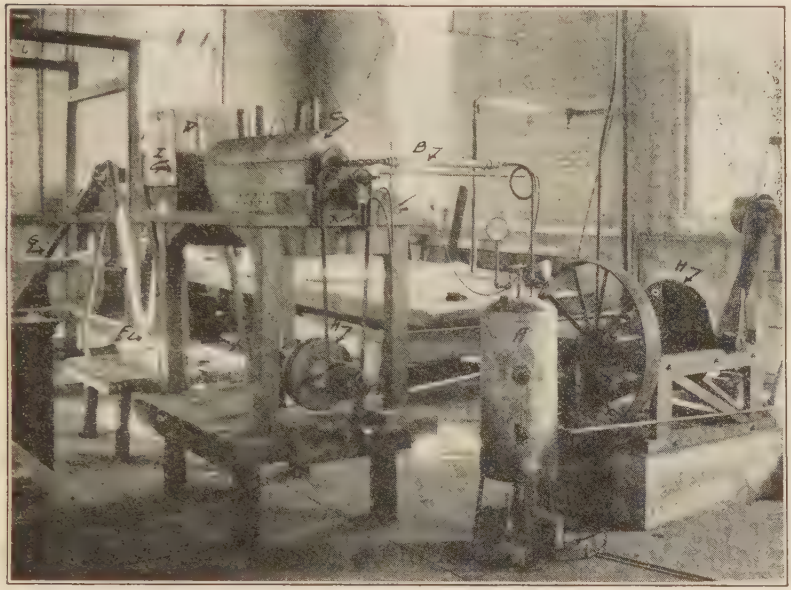
at will, within certain well defined limits, by the intensity of the heat applied and by its manner of application. The cardinal principle, then, of any method of retorting must be absolute heat control.

As before mentioned, all of the "kerogen" will not produce oil gas but some gas will be formed which is not condensable but which, nevertheless, is very valuable as it may be utilized, either by burning directly or in gas engines, as a fuel to operate a plant. In general it may be said that the ideal retort so far as the production of oil is concerned will be the one in which a maximum of oil is made with a minimum of fuel gas though all the fuel gas made must be conserved.

There is, in addition to the "kerogen" present, a varying amount of nitrogen in the Kentucky Shales a large part of which may be recovered as ammonium sulphate under the proper conditions of retorting. But a maximum recovery of ammonium sulphate requires somewhat different conditions than if oil alone be considered. Steam must be used and a high enough temperature developed to dissociate this steam so that it may react with the nitrogen to form ammonia which, in turn, by being passed through sulfuric acid, will form ammonium sulphate. But, as previously indicated, a higher temperature than that necessary to evolve the oil gas is undesirable because of the danger of "cracking" the oil gas into fuel gas and thus curtailing the production of oil. In the ideal retort, therefor, all the oil gas must have been evolved and withdrawn before the temperature is raised to such a point that maximum ammonia recovery is obtained. Also, for the latter result, steam must be used.

It has been stated that dissociated steam reacts with the nitrogen in the shale to form ammonia, but it does more than that. It also reacts with the fixed carbon in the shale, that is the carbon that is not volatilized by simple heating, to form water gas thus increasing the amount of fuel available for plant operation and this point is one that should be borne in mind because if enough gas can be made in retorting to supply all or most of the fuel needed one of the greatest items

of running cost is practically eliminated and the plant is almost self contained.



A LABORATORY UNIT RETORT.

This view, also taken from the driving or steam inlet end, shows the retort with the cover on and all connections made ready to operate. The boiler, superheater and driving mechanism are shown in the foreground while the dust catcher and part of the condenser system shows in the left background.

In addition to the products named a number of the reliable commercial laboratories state that water soluble potash to the amount of from four to thirty-eight pounds per ton of shale may be recovered from the spent material that has passed through the retort. While the retort used has nothing to do directly with the amount of potash recovered nevertheless it has an indirect bearing in that the more finely divided the shale the easier for the water to dissolve out the potash. In other words maximum potash recovery means fine grinding. On the other hand fine grinding costs are high so that an economic equilibrium will have to be found which, I think, may be when the shale is crushed to about pea size. From what has been said it will be seen, then, that the ideal machine will

be one that will treat shale crushed to about pea size or a little larger not only for the easy liberation of the potash content but also for the more efficient and rapid evolution of oil and fuel gas with consequent diminished danger of "cracking" and the better interaction of dissociated steam with the nitrogen and fixed carbon of the shale with the consequent decreased time of treatment and increased amount of both ammonium sulphate and water gas.

At the present time not enough research work has been done to determine what, if anything, may be done with the retorted or spent shale. Some of the suggested uses which are worthy of further investigation are as a raw material for vitrified brick, which seems reasonable as the spent shale consists of about fifty per cent silica, as a base for Portland cement, the necessary ingredients which may be lacking being added, as a road material when mixed with the tar or other material from the refining of the oil, etc. In all these suggested uses a fine degree of division is necessary giving additional proof that the ideal retort should be designed for treating fine, not coarse, material.

Bearing in mind the above it becomes evident that the ideal retort for the treatment of Kentucky oil shales must be one in which (1) absolute heat control is available, (2) the oil must be educed and withdrawn first and the bulk of the ammonia and water gas later, (3) provision must be made for treating shale of at least pea size, (4) there is practically no leakage of gas from the retort or of air into the retort and, preferably, a slight vacuum in the retort rather than a pressure. These are the technical points, but, in addition, there are the equally important commercial ones of (1) low first cost, which means easily obtainable and cheap materials of construction, (2) low operating costs, which includes a minimum of skilled labor required, (3) low upkeep and repairs, which means simplicity of design, (4) maximum thruput per unit compatible with efficient recovery of products, (5) continuous operation, which means no complicated parts and all parts liable to breakage easily reached for repairs.

With the above qualifications for the ideal retort in mind, an effort will be made to analyze some of the more prominent makes of retorts on the market today for their availability for use on Kentucky shales and to see how closely they conform to the ideal conditions outlined. The data on which these analyses are based is taken largely from that furnished by the owners of the various machines described and discussed. An attempt has been made by the writer to verify all statements submitted, but it is not impossible that some errors or misstatements may have slipped in.

All the retorts designed for the dry destructive distillation of oil shale fall naturally into two grand divisions, (1) vertical retorts which include the Scotch and modifications of the Scotch and (2) horizontal retorts in which the retort itself is stationary and the shale is conveyed through it by mechanical means or in which the retort itself revolves. The above classification covers all the known methods of educing oil from shale, except one. This latter one is a digestive process in which the pulverized shale is treated in hot oil instead of by a dry heat. A description of this essentially different method will be taken up later in the proper place.

THE SCOTCH PROCESS.

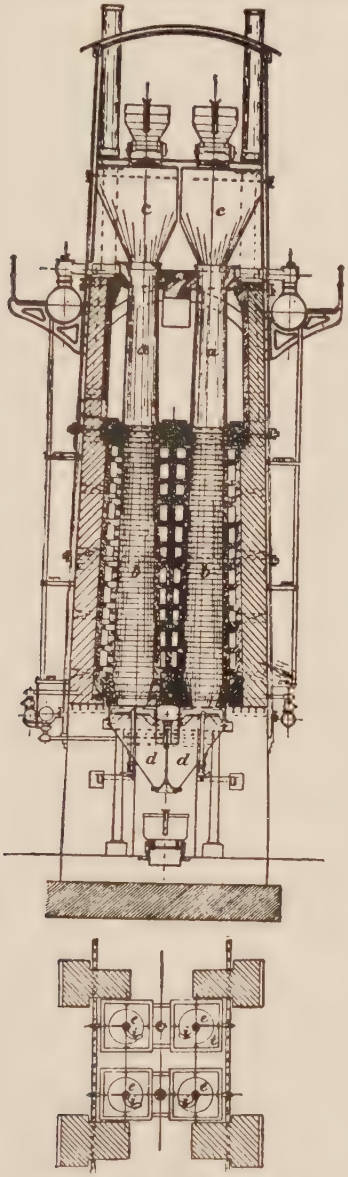
The shale industry in Scotland has been established since 1850 and the retort first used has necessarily undergone many changes since that time. Nevertheless the Pumpherston retort of today, which will be taken as an example of Scotch practice, is quite similar to the Young and Beilby retort which was patented in 1881.

The Pumpherston retort first came into extensive use in 1896 and twenty years later there were some fifteen hundred retorts of this type in operation in Scotland.

As shown in the figure, the shale, first crushed to a size not greater than six inches square, goes to the charging hopper "c" from which it passes into the upper, cast iron portion of the retort "a" in which the actual distillation takes place. This portion of the retort is 15 feet long, 2 feet in diameter at the top and 2 feet 4 inches at the bottom and is heated

externally, to a dull red heat, the oil vapors passing out below the hoppers through an iron main 2 feet 6 inches in diameter. The shale then slowly works its way into the lower portion of the retort "b," which is made of fire brick. This portion is 20 feet in length, 2 feet 4 inches in diameter at the top where it joins the cast iron portion and 3 feet in diameter at the bottom. Here the shale is subjected to a temperature sufficiently high to burn off all the carbon from the oil spent shale and, this being done at a high temperature in the presence of steam, ammonia is produced by the hydrogen of the steam uniting with the nitrogen of the shale, about sixty per cent of the total nitrogen being converted into ammonia and recovered. At the bottom of the fire brick portion there is a disk shaped table "e" which supports the column of shale in the retort this table being provided with a revolving arm "i" which removes the spent shale and maintains a movement in the shale column by revolving at regular intervals. This arm discharges the shale into the lower hopper "d" extending underneath several retorts and converging in such a manner that a single line of rails running below the center will allow the exhausted shale to discharge into cars from whence it is removed to the dump. Both portions of the retort are heated externally by the gas made in the process, when in sufficient amount, steam being introduced a short distance above the disk "e." In this type of retort a thruput of from four to five tons per day may be worked.

The Scotch Shales are mined underground, the method used being very similar to that used in mining coal in this country. The roof is supported by pillars and usually about twenty-five per cent of the shale is left under ground in mined out workings. The shale is carried to the surface, broken into pieces not more than six inches square, and then goes to the retorts. The gases are withdrawn from the retort as indicated in the the description of the retort, the oil gases condensed and the fuel gases scrubbed to recover ammonia and gasolines carried over and then used to heat the retorts. The spent shale goes to the dump. The crude oil obtained is then refined by meth-



DIAGRAMATIC SKETCH OF A PUMPHERSTON RETORT.
This retort and others similar to it are much used in Scotland for the extraction of oil and by products from shale.

ods similar to those used in refining natural petroleum though differing somewhat in some respects.

The shale now being retorted yields an average of almost 24.5 gallons of crude oil and about 35.7 pounds of ammonium sulphate per short ton with an average yield of about 9,800 cubic feet of fuel gas of a heating value of about 240 B. t. u. per cubic foot. According to Doctor Alderson of the Colorado School of Mines the profit on each ton of shale mined is approximately two shillings or, under normal rates of exchange, fifty cents. At the present time the entire shale industry of Scotland is controlled by Scottish Oils, Ltd., which is, in turn, controlled by the British Government.

The Scotch process as practiced today represents the evolution taking place in some sixty or seventy years and is undoubtedly very well suited to the conditions under which it is required to operate. The Scotch plants are in the midst of an industrial area where labor is plentiful and cheap, they have no domestically produced petroleum to compete with and there is a large demand for the ammonium sulphate produced. Under these conditions the small thruput of from four to five tons per day and the more or less wasteful methods of heat utilization are possible whereas in this country, under different conditions, it is doubtful if it would do at all.

The chief objection to the Scotch method of retorting oil shales, then is its small thruput per day which, with the necessarily large capacity demanded by steam shovel methods of mining, which will be used in Kentucky, would necessitate a large initial outlay for plant and a huge plant site.

The Scotch retort has been proved to be practical in Scotland and would undoubtedly work here, fulfilling as it does most of the requirements of the ideal retort but it is certainly not the most efficient that can be devised for Kentucky practice and, therefore, should not be considered too seriously.

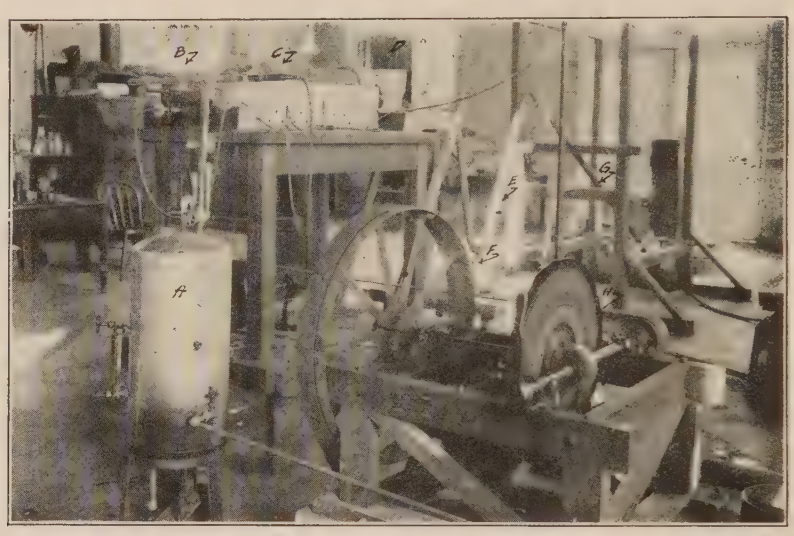
THE PROCESS DEVELOPED AT THE UNIVERSITY OF KENTUCKY.

This process has been developed by the writer and Mr. E. E. Hedges of New York, during about two years of research

work and the laboratory model in use at present is shown in the accompanying cuts.

It consists, essentially, of a hollow, revolving cylinder 30 inches long by 6 inches in diameter driven by a friction drive, at about fourteen revolutions per minute though this speed may be varied, a boiler for generating steam, a box with an interior baffle, into which the gas from the retort is first passed and the purpose of which is to catch any dust that may be carried out of the retort in the gas current, and a condensing system to condense the oil gas.

Cut number one gives a general view of the apparatus. In this cut "A" is the steam boiler heated by burners beneath it and in which about twelve pounds of steam is maintained during the duration of a run. "B" is a length of 2-inch pipe used as a superheater for the steam and heated by a burner beneath it as shown. "C" is the revolving cylinder or retort proper shown with the cover off. This cover is put on when the machine is operating in order to cut down radiation losses. "D" is the dust box or dust catcher into which the gases from the retort are first discharged and in which is a baffle placed at about sixty degrees from the horizontal. This baffle forces the gas current to make an entire change of direction so that the dust particles may drop out due to the action of gravity. The size of the box which is a 16-inch cube with a pointed bottom is also such as to retard the velocity of the gas current and in this way also assist in forcing the dust particles out of the gas stream. "E" is a V-shaped air condenser with trap "F" at the bottom of the V where the easily condensable gases are recovered and "G" is a straight, water cooled condenser where the more difficultly condensable gases are obtained. "H" is the driving mechanism with friction drive the latter giving an opportunity to vary the speed of the cylinder at will. "X" is a burner for supplying the necessary heat beneath the revolving cylinder, and it extends the entire length of the cylinder. The fuel used is natural gas, though the fuel gas made in the process could and would



SIDE VIEW LABORATORY MODEL.
This view, taken from the driving end, shows the retort in position but with the cover off. A good view is given of the driving mechanism, the steam boiler and superheater with the dust catcher and condensers showing in the background.

be used in a plant in the field. Fuel gas could be used in the laboratory were the proper apparatus available.

Cut three is a view from the condensing end of the apparacylinder in place. The letters stand for the same parts as previously outlined. In addition "I" is a ¾-in. pipe let into the dust-catcher in which a thermo-couple is placed and the vapor temperatures thus noted.

Cut two is another general view with the cover over the tus showing the condensing system more in detail, the letters indicating the same parts as in the preceding print. There is an opening, not shown, in the discharge end of the retort, that is the end next the dust catcher, where the gases are discharged, for charging and discharging the shale. During the operation this opening is kept carefully closed by having the support trunion on that end screwed in.

Method of Operation.

Bearing the above description in mind, a brief outline of the mode of operating should be readily understood. Ten

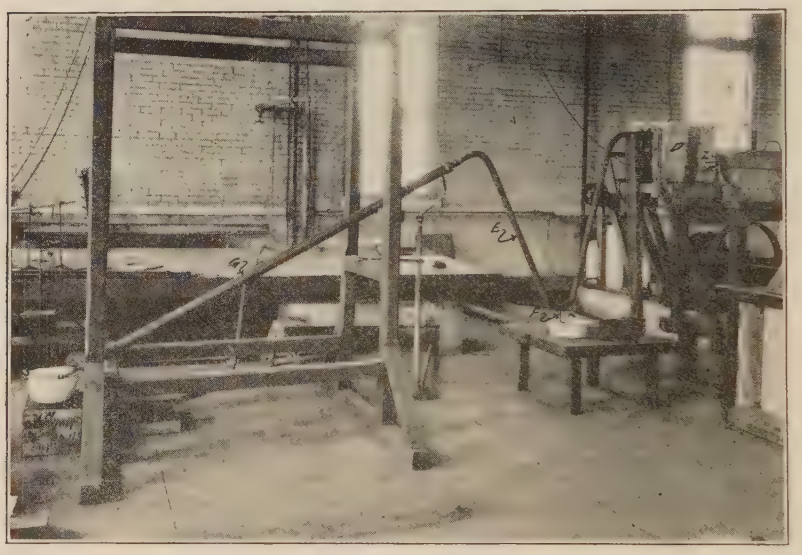
pounds of shale crushed to about quarter inch size and smaller particles are placed in the retort, the opening closed, and the retort put into position. A low fire is then turned on and the driving mechanism, a motor, is started. All joints are connected up and tight at this time, with the exception of the stuffing box which connects the stationary steam super-heating pipe and the revolving cylinder. The steam supply to the superheater is off and the boiler shows about ten pounds of steam. The heating is continued slowly till gas, evolved from the shale, shows at the stuffing box when steam is turned through the superheater to expel any water and insure the steam being dry before entering the retort and then the connection is made. A small amount of steam, just sufficient to sweep the gases out of the retort into the dust catcher and condensing system is then turned on. From this time on till the end of the run steam is continually passing through the retort, not only to act as a scavenger but also for its chemical action on the gases and the shale.

The heat is now gradually increased, temperature readings on the vapor being taken at frequent intervals, till no more oil appears either at the trap in the air condenser or at the end of the water condenser and very little gas is being shown at the latter point, the above conditions indicating that all the oil has been educed from the shale. The cooling water is now cut out of the water condenser and a full head of steam allowed to pass through the entire system in order to remove any oil that may adhere to the condensing pipes. The steam and the heat are then cut off, the rotation stopped and the retort is ready to be discharged.

The dust and whatever heavy oils that may have condensed in the dust catcher are then removed through the bottom of the box through an opening provided for that purpose and, after dewatering, are subsequently treated in a small stationary retort in order to recover their oil content. The oil which has been collected at the trap in the air condenser and at the end of the water condenser is now freed from water, mixed with the oil recovered from the dust box and carefully

measured, computations being made to give the results in gallons of crude oil per ton of shale.

Although the machine appears to be, and is, very simple, nevertheless it represents the evolution of the basic idea during a period of about two years of experimentation. The results obtained, to date, have been very satisfactory. The above described machine is the trial model of a commercial machine of which great things are expected.



GAS DISCHARGE AND CONDENSER.

This view shows part of the retort, at the extreme right, and in the center and left the condensing system. Since this picture was taken the pan, to hold the condensed oil, shown at the extreme left, has been replaced by a series of bottles connected to a suction thereby allowing scrubbing of the permanent gases.

This commercial machine will be 35 feet long by 4 feet in diameter and will have a capacity of about 25 tons of shale per day. It will consist of a revolving cylinder set at a slight angle to the horizontal the pitch being just sufficient to force the shale to move through the retort at the correct speed. The shale, crushed to about pea size, will be fed continuously at one end and discharged continuously at the other. A graduated heat will be maintained in the cylinder being just suffi-

cient to keep the gases from condensing in the feed end and increasing uniformly through the length of the retort to about 900 degrees F. at the discharge end. In this way the oil gases will be evolved from the shale as it travels through the retort, those which are formed first coming off at a low temperature and so on, and, as the gases are swept out and withdrawn through the feed end practically as soon as formed they will never be subjected to a higher temperature than that at which they are formed and, therefore, will run no danger of being cracked and changed into fuel gases.

At the lower or discharge end of the retort superheated steam will be admitted which will serve not only as a medium for sweeping the gases from the retort but will also be beneficial to both the quantity and quality of the oil made.

The oil spent shale, after it has been automatically discharged from the retort will pass into a water gas producer where the temperature can be raised sufficiently high so that steam, introduced in the usual way into the producer, will be broken up so that it will react chemically on both the nitrogen and the fixed carbon of the shale in the former case to give an increased yield of ammonia and, therefore, of ammonium sulphate and in the latter case to make water gas and thus increase the yield of gaseous fuel.

The spent shale as it is automatically discharged from the producer may be water treated to recover water soluble potash and then taken by conveyor belts or otherwise to the dump. The oil gas will be condensed and refined and the fuel gas scrubbed to recover light oils, ammonia, etc., and led to gasometers from whence it can be withdrawn, as needed, for fuel purposes.

A great deal cannot be said about the results to be expected commercially from this retort as no commercial unit has yet been built although one is in process of construction at the present time but the machine as outlined comes as near as any known to meeting the conditions of the ideal retort and the results from the laboratory model in both quantity and quality of oil and by-products obtained have been such as to indicate

that this machine will work as well if not better, on Kentucky shales, than any of the other processes described. No claim is made that this is the only machine that will take the oil from shale, but the results obtained taken in conjunction with its simplicity, low first and running costs, and large thruput per day would seem to show that it is one of the few, at least, that may be successfully utilized commercially on Kentucky shales.

THE RYAN PROCESS.

As previously stated, the Ryan Process is not one of destructive distillation, but is claimed to occupy "the middle ground between the range of a simple solution of contained oils and substances in some solvent under moderate temperatures and that of destructive distillation. It generates no gas———."

The Ryan Process consists of pulverizing the shale till about fifty per cent will pass a one hundred mesh screen. It is then fed, by means of a screw conveyor, into air tight kettles of hot oil, which has been stripped of its lighter fractions. The shale is fed near the bottom of the kettle and beneath the surface of the oil at a temperature above 680 degrees F., the approximate working temperature of the process.

The whole mass is then agitated by means of revolving arms. The hydrocarbons of the shale is split up and a distillate comes off with the characteristic odor of shale oil without producing any appreciable amount of gas. This distillate, which consists largely of the lighter oils formed, begins to come off immediately after the introduction of the shale and is condensed and recovered. After this part of the process is complete the digestive oil and the shale residue are removed from the kettle and separated mechanically by means of a centrifugal motion. They are twice washed with light oils during the operation. The nearly dry shale is then treated destructively in another kettle to recover wash oils and the remaining portions of shale oil which were not liberated by simple digestion. In this second stage, which is simply destructive distillation, some non-condensable or fuel gas is formed. It will be further noted that there is no recovery of ammonia.

The estimated costs of treating a ton of the Western Shale on the basis of a thousand ton a day plant are given as 75c for mining and delivery to digestor plant, crushing and grinding 15c, operation of digestor plant 25c, overhead, interest, depreciation, etc., 35c, making a total of $1.50 per ton treated, which compares very favorably with estimated costs of other processes. This estimate may be conservatively regarded as too low rather than too high.

To recapitulate, the Ryan Process consists of four separate and distinct steps each one requiring its own separate and distinct machinery, i. e. pulverizing, treating in the digestor, separating partially spent shale and digestion oil, treating this partially spent shale destructively. The claims for the process are: (1) a much larger oil recovery than by destructive distillation, (2) twice as much oil or more, (3) a better quality of oil so far as degree of unsaturation is concerned, and (4) all this at no more and possibly a lesser cost than that of other processes. Against these claimed advantages are the evident disadvantages of, (1) complication of plant with all the consequent chances of break downs and necessary care and skill in operation, (2) magnitude of plant for a given tonnage comprising as it does not only a digestive but also a destructive plant, (3) very little fuel gas made necessitating the inconvenience and cost of an extraneous fuel supply, (4) no ammonium sulphate made which puts the burden of profits on the oil alone or, at best, on the oil and spent shale. Taking everything into consideration, then, a comparison of the Ryan Process and any destructive distillation process is one of economic balance. Will a greater recovery of oil with a less degree of unsaturation be worth more than the loss of gas and ammonia and the greater magnitude and complication of the commercial plant?

For some six months a laboratory plant of this process has been in operation on Kentucky shales in the Mining Laboratory at the University of Kentucky and the writer has had an excellent opportunity for careful study of it. At the same time the machine developed at the University has been in operation

at the same place on the same shales. While the Ryan Process in some cases has shown a greater recovery of oil of a greater degree of saturation still the difference between the results from the two processes have not been very marked, never approaching two to one, and there is no question but that destructive distillation as exemplified in this retort, at least, is much simpler as well as showing fuel gas and ammonia recovery.

There is no question but that the Ryan Process will produce oil and a lot of it, probably more than most if not all processes of destructive distillation, but it fails to meet two of the important requirements of the ideal process, viz. simplicity which includes the time element or thruput per day per unit and diversity of products and, in addition, its claimed superiority of producing oil with a greater degree of saturation than that produced destructively is not, according to some refinery engineers, nearly as important as it may seem.

The successful commercial application of the Ryan Process to any particular problem, then, will depend entirely on whether the increased oil yield will counterbalance the undesirable features enumerated. It would seem as though there is much room for doubt whether this process will be any better, or as good as the best methods of destructive distillation from a profit-making standpoint which, after all, is the criterion by which all processes must be judged.

THE SIMPSON PROCESS.

This system of working oil shales is the result of some six years' work on the subject by Mr. Louis Simpson of Ottawa, Canada, and falls under the classification of vertical retorts. In this process the oil shale, after mining, is sent to the crusher house which contains a coarse crusher, a fine crusher, two screens to remove the fines and to return the oversize to the crusher, and a magnetic roller to remove "tramp iron." The shale, crushed to pass a half inch but be retained on a quarter inch screen, is then conveyed into and through dryers heated by the waste gases from the steam boilers after the main part of their heat has been removed in order to preheat the gases

for educing the oil from the shale as will be explained later. These dryers are for the purpose of furnishing shale to the retorts of the same physical characteristics at all times of the year. From the dryers the shale goes again to screens to remove the last of the fines and from these to bins over the retorts.

From the bins the finely crushed shale passes into each of the two chambers of a double retort being fed by a special feeder which feeds continuously in a small dribble. These chambers are vertical and rather narrow in width and so designed that the top of the shale in each chamber assumes the shape of a pile with two long sides or slopes thereby presenting the greatest possible surface to the action of the preheated gases with which the space unoccupied by the shale is kept filled. These two chambers join at the bottom of the retort and the shale is removed continuously at this point by means of two discharge rollers.

The heat required to produce the oil gas from the shale is furnished by admitting preheated gases into the retort in direct contact with the shale, there being no outside application of heat. These gases are the product of a previous operation and are admitted at several points two of which are located at the feed end of the chamber. The volume of these gases can, of course, be regulated as desired. It is claimed that not only do these preheated gases heat the shale to the necessary temperature for educing the oil but also act as a carrier for the oil vapors formed by their action and in addition act as a diluent thus lowering considerably the vapor pressures and temperatures required for the action.

The gases and oil vapors are removed from the retort at several points through holes specially designed so that they will not become clogged. The light-oil-vapor-gas mixture comes off first and the vapors are condensed by being passed through the water cooled condensers the heavy-oil vapors being removed and condensed separately. The water used in condensing the light-oil-vapors is used again in the heavy oil

condensers from whence it is delivered at a temperature sufficiently high to permit its being fed directly into the boilers.

The retort chambers are made of steel plates and a bench of retorts, consisting of four double retorts, is enclosed on all four sides by an inner steel wall welded to make it gas tight, a layer of heat insulating material and then another wall of steel plates.

The shale, after being discharged from the retorts, is cooled and taken to the by-product plant where it is treated to recover ammonia. The oil vapors pass into condensers from which the fixed gases are passed into washers for the double purpose of recovering the non-condensable gasoline and also any ammonia that may have been carried away. From here the gases pass to gas holders or gasometers from which it is withdrawn for the following two cycles: (1) gas holder to steam boiler to gas preheater to shale dryers to by-product recovery or air, (2) gas holder to gas preheater to retorts to condensers to exhausters and washers and back to gas holders.

The costs of retorting not including mining the shale, refining the oil or treating the by-products are given by Mr. Simpson as being 60¾ cents per ton. This figure includes taxes, depreciation, etc., and is figured on an average wage scale of $5.00 per day of eight hours.

The salient points to be noted in this process are: (1) heat for educing the oil gas from the shale is furnished on the interior of the retort by means of preheated gases, (2) no steam is used in the retort, (3) nothing but oil is recovered in the retort with the exception of slight amounts of ammonia evolved at the comparatively low temperatures used, (4) the bulk of the ammonia is recovered in the by-product plant after the oil has been removed from the shale in the retort, (5) very efficient heat conservation.

Mr. Simpson, who has examined the deposits of shale in Kentucky, states that he has not the least doubt but that using his process the retorting of Kentucky shales is commercially possible.

THE WORK OF MR. R. M. CATLIN.

Mr. R. M. Catlin has been experimenting for some years on a deposit of shale in Nevada and states, "My work has been entirely experimental and aimed entirely toward the economic treatment of our deposit, which is a paraffin shale containing no asphalt. In the course of years I have tried a great many methods and have no idea which of them may be of interest to your problem. In any case I am not prepared to publish my notes till I have completed my research."

THE WALLACE PROCESS.

This process, devised by Mr. G. W. Wallace of East St. Louis, Ill., is one that has attracted a good deal of favorable attention recently. Its classification places it under the head of vertical, intermittent retorts.

The retort proper consists of a vertical truncated pyramid with steeply sloping sides the large end being at the bottom and the dimensions being 7 feet long, 15 inches wide and 14 feet high with a thruput per oven of forty-eight tons per twenty-four hours. Around the outside of the retort enclosing walls are built and in the space between the retorts and these walls the heat for educing the oil gas from the shale is applied. The retort is, of course, tight closed at top and bottom. In the center of the retort is placed a metal duct which extends from the bottom to nearly the top and is of such a size that there is space of 3½ inches between it and the inner walls of the retort which space is kept filled with shale. This duct is covered at the top but is perforated with many holes around its perimeter and down its length through which the gases educed from the shale are withdrawn. The bottom of the perforated duct is connected to a suction pipe so that a slight vacuum may be maintained in the interior of the retort at all times and thus serve to withdraw the gases as soon as they may be formed.

The operation is as follows: The 3½-inch annular space between the walls of the retort and the interior duct is filled with shale crushed to a size of up to 2½ inches, suction is applied through the perforated duct and heat is given on the

outside of the retort the maximum heat, 1400 degrees F., being at the bottom. The heat attacks the shale nearest the outside of the retort first and evolves gases which are immediately drawn, by suction, through the cooler portions of the shale and into the perforated duct from where they go into condensers. The heat gradually works in toward the duct due both to the heat applied from the outside and that given off by the hot gasses as they pass through the cooler shale the evolved gases being continually withdrawn through the coolest portions of the retort, into the center duct and so passed out into the condenser system. In this way the gases are never subjected to a higher temperature than that at which they were formed and danger of cracking is eliminated. This action continues till all the gas has been evolved when the retort is shut down, the bottom removed and the spent shale discharged. At the same time the perforated center duct is removed and replaced by a fresh one thus enabling the used pipe to be thoroughly cleaned at leisure. The retort is then ready for a fresh charge and the operation is repeated.

The special points about this retort are: (1) the evolved oil gases are never subjected to a higher temperature than that at which they are formed thus eliminating the danger of cracking or breaking the oil gases up into non-condensable or fuel gas, (2) the heat is applied externally, (3) no steam is used in general though it may be used if desired, (4) the process is intermittent which latter point, in the opinion of the writer is apt to be a serious disadvantage.

As fare as costs and profits using this process are concerned I quote from an article by Floyd W. Parsons in the March 20, 1920, number of the Saturday Evening Post. "The other day, in an effort to get authentic operating figures, I sought Mr. Wallace and procured from him a comprehensive estimate of actual working costs based on preliminary but large scale practice. Reduced to the simplest form his figures indicate that at the present time (March, 1920) the cost of erecting a carbonizing plant to treat 90,000 tons of shale annually would be $220,000. The average cost per ton of shale carbonized would

be $1.37 divided as follows: fixed charges, including insurance, taxes, repairs and depreciation—32 cents; labor—50 cents; quarrying the shale 45 cents; extraction of ammonia—10 cents, making a total of $1.37. If the shale cannot be quarried and must be mined instead the cost would be $1.25 rather than 45 cents as stated above. According to Mr. Wallace the United States Bureau of Mines is authority for the statement that the oil can be topped for gasoline at a cost of 10 cents a barrel. He believes this figure is correct. The total cost of mining, carbonizing (retorting) and refining each ton of shale would be $2.47 divided as follows: overhead and transportation—50 cents; carbonizing—$1.37; cost of refining—60 cents; making a total of $2.47.

"As to the revenue to be derived from each ton the figures produce the following: Gasoline, 8.9 gallons @ 20 cents per gallon, $1.78; paraffin, 23 pounds @ 6 cents per pound, $1.38; ammonium sulphate, 17.2 pounds @ 5 cents per pound, 86 cents; lubricating oils, 17.65 gallons @ 20 cents per gallon, $3.53; total, $7.55.

"Deducting all the costs from the above revenue we have a net profit in the operation of $5.08 per ton. Mr. Wallace bases his figures on a yield of 42 gallons of oil per ton. * * * He says that it is not unusual to expect that the oil will refine out from $7.00 to $8.00 per barrel."

Mr. Wallace has very kindly supplied the writer with the following data concerning a plant that he has erected for the D'Arcy Exploration Co., near Moneton, N. B. The plant, which is in daily operation, consists of one oven of 15 cubic feet capacity. It is eleven feet high, has an average cross section of 14 inches by 30 inches and holds a charge of from 800 to 1,000 pounds of shale. The plant is complete with condensers, scrubbers and all auxiliary equipment.

The average results obtained in the above plant after an operation of one month and with approximately 100 tons retorted, is as follows: (1) Average time of retorting shale, 2.13 hours; (2) pounds of shale retorted per square foot of retort per hour, 5.01; (3) yield oil per ton, 28.21 imperial gal-

lons (35.85 U. S. gallons); (4) laboratory yield of a check sample by Scotch testing method, 28.27 imperial gallons; (5) specific gravity of crude oil, .898; initial boiling point, 187 degrees F.; end point, 702 degrees F.; (6) crude naphtha, 22.95%; green oil, 71.80%, distillation loss, volume, 5.25%; coke from oil, per cent by weight, 3.55%; unsaturated hydrocarbons, crude naphtha, 7.16% and green oil, 27.60%.

It is not known that any Kentucky oil shale has been tested in a Wallace retort. There is no reason why it should not work as well, or give as good results, however, as shale from any other locality.

THE GALLOUPE PROCESS.

This oil shale retorting process developed by Mr. J. H. Galloupe of Denver, Colorado, has a vertical retort and is of the modified Scotch type. It consists, essentially, of two cylinders one placed concentrically within the other leaving an annular space of 4 inches between the two in which space the shale is placed. The inner cylinder is 16 inches in diameter and the outer one 24 inches the height varying from 18 feet to 21 feet according to distillation requirements. Both the outer and inner cylinders are equipped with ledges or vanes placed spirally and so designed that as the inner cylinder slowly revolves there will be a constant agitation which not only prevents clogging but also moves the shale slowly from the top to the bottom of the retort.

The heat is applied to these cylinders externally, that is on the interior of the inner cylinder and on the exterior of the outer one, and in both cases from the bottom upward so that the lower portion of the retort is subjected to the greatest temperature, the temperature range being from 1100 to 1340 degrees F. at the bottom to 212 degrees F. at the top. The oil gas is withdrawn as formed and it is claimed that partial fractionation takes place in the operation of retorting, that is, that by withdrawing the gases from different points and then condensing these gases separately, different grades of oil are obtained without further refining. In the opinion of the writer it is an extremely difficult if not impossible thing

to get a satisfactory product in this way and it would be preferable to condense all the oil gas together and then refine the crude as is done in ordinary practice with natural petroleum.

The retort is so constructed that the lower portions which are subjected to the greatest heat and wear are easily removed and replaced without causing any long shutdown. The materials used in the retort are wholly cast iron and the thruput per 24 hours is given as eight tons with high grade and twelve tons with low grade shale.

The salient points of this retort are, (1) continuous movement and agitation of shale through a vertical annular space the movement being due to slow rotation of the inner cylinder, (2) application of external heat to two sides of the shale at the same time, (3) no steam used. So far as is known, no Kentucky oil shale has been treated in a Galloupe retort.

THE DAY PROCESS.

This process developed by Dr. David T. Day of Washington, D. C., is of the horizontal type of retort. The retort proper is made of steel and the shale is advanced through its length by means of a screw conveyor. The shale is crushed to egg size, fed into the retort and passed through at the rate of 20 tons in 34 hours. The heat is applied externally and is furnished by the waste gas, the temperature required being 709 degrees F. The gases and vapors are withdrawn as in an oil still. It is understood that this process has been tried out in California and Texas shales, but so far as is known no experimental work has been done on the oil shales of Kentucky by this process.

THE JENSON STAGE EDUCTION PROCESS.

This system of retorting, invented by Mr. J. B. Jenson of Salt Lake City, Utah, was designed specially for use on the fluxing shales of the West and the retorts are of the horizontal type. A commercial retorting unit, it consists of nine, horizontal, cast iron cylinders, eighteen feet long, placed at three-foot centers one above the other, the whole being enclosed in brick work, and the shale being moved through each cylinder

by means of screw conveyors. The fuel used is gas formed in the process and it is applied under the lower chamber, the temperature required being 250 degrees F. for the first or top cylinder and graduating to from 900 to 1200 degrees F. for the last or bottom cylinder, this latter temperature varying with the structure of the shale. As stated above the heat is applied under the lowest cylinder and the hot gases are then led progressively upward and around each of the cylinders above being finally discharged at the top and thus giving the graduated heat mentioned. The thruput is given as 50 tons per 24 hours and the gas and oil vapors evolved during the process are withdrawn from the retorts by an exhauster through four pipes spaced at about equal intervals up and down the height of the nine cylinders. By using this means of collecting the vapors and by then condensing the vapors from each pipe separately a partial fractionation of oils in the retorting process itself is claimed.

The shale, grading in size from a half an inch down to fines, is introduced into one end of the top retort through a hopper, which hopper is kept full thus forming an air and gas tight seal. The screw conveyor then carries it through this upper cylinder where it is subjected to a temperature of about 250 degrees F. as a consequence of which the water is driven off and the shale warmed. After passing through this upper cylinder the shale drops down into the one next below where it is picked up by a screw conveyor and passed through this second cylinder the direction of travel being opposite to that taken in the first case. Here it is subjected to a slightly increased heat and the vapors that will come off at this temperature are educed.

After passing through the second cylinder the shale drops down to the third one and passes through it in a direction opposite to that taken in the second one and here it is again subjected to a slightly higher temperature where the gases evolved at the temperature used are educed. This procedure continues, as outlined, till the shale has passed through the entire nine cylinders, at which time all the oil and gas will

have been driven off, when it is discharged by screw conveyor into water this water affording a seal against any leakage of air into the retort or of gas from it. Treating the shale in stages in this way is claimed to prevent any breaking up of the oil gases formed and to also overcome the fluxing tendency of high grade shales. Steam may be used when water is available, otherwise not. When used it is introduced into the lowest, which is also the hottest, cylinder.

The outstanding points about this system are (1) stage eduction, that is, practically a separate treatment of shale in each of nine cylinders, (2) shale conveyed through each cylinder by screw conveyor, (3) heat applied externally, (4) vapors withdrawn at four separate and distinct points and condensed separately.

As before mentioned this system was designed primarily for treating the fluxing shales of the Western part of the United States and, this being the case, it is necessarily overcomplicated for the non-fluxing shales of Kentucky. However, Mr. Jenson has recently "perfected two additional retorts one of which was specially designed for the low grade non-fluxing shales in which the ammonia product is of special interest. This retort has large capacity, operates cheaply and is not expensive either to construct or to keep in repair. "This retort is known as the Devonian Type." He continues, "Our high pressure retort should also be applicable to your Kentucky shales although it was designed originally to treat the metal bearing shales of Colorado and Utah. It is a high pressure retort and almost invariably gives an increased yield of oil over other types of retorts and was not designed for the recovery of ammonia."

The two retorts mentioned and designed by Mr. Jenson are not yet at the point in their development where detailed information can be given, due to the fact that foreign patents have not yet been allowed. Mr. Jenson, himself, realizes that stage eduction is not the real solution of the problem for Kentucky shales, and already has several improvements which he hopes will perfect his process for use here.

THE SCOTT PROCESS.

This system of oil shale retorting, owned by the General Eduction Co. of Colorado Springs, Col., is one that has been mentioned rather frequently in connection with Kentucky shales. In fact, the Devon Oil Shale Products Co. of Cincinnati is reported at the present time to be making an installation of an eight retort plant at its property near Clay City.

The retort is of the vertical type and is made in sizes to have a capacity of twenty, thirty or forty tons per 24 hours, the dimensions with the latter capacity being 12x22x50 feet high. The materials of construction are steel, silica, carborundum brick and concrete. The retort proper consists of an upper and a lower portion connected by an expansion joint so designed that the connection between the two portions may be closed when desired. The vapors educed from the shale in the lower portion of the retort may either be withdrawn through an outlet pipe at the top of this portion, that is, at about half way of the total height of the retort, or else may be passed around the expansion joint and be brought into contact with the shale in the upper portion of the retort, thus preheating it. There is also a valve in the by pass pipe so that the vapors may be prevented from entering the upper portion of the retort if desired.

In this upper part there is a feeding arrangement and an outlet pipe to remove the oil gases, while the bottom of the lower portion is closed, the shale being removed by means of a screw conveyor, everything being kept gas and air tight.

A brick enclosing wall is built around the retort proper in such a way as to leave an annular ring, and it is here that the gas is burnt to supply the heat for educing the oil from the shale, the hot waste gases of combustion being led off through a stack. The draft is regulated by dampers placed in the pipe leading from the annular ring into the stack. Steam, superheated to 900 degrees F. at atmospheric pressure or about 687 degrees of superheat, is introduced into the bottom of the lower portion of the retort and, the temperature being sufficiently high, is broken up so that it reacts with both the

nitrogen and fixed carbon of the shale to form ammonia and water gas respectively as well as acting beneficially on the oil vapors formed.

For purposes of illustration suppose the retort to be running. The upper portion is filled with shale crushed to from 1 inch to 1.5 inches and gases, formed in the lower portion are passing through it, the shale itself being stationary. This results in this shale being preheated to a certain extent thus driving off the moisture. At the same time a temperature of from 900 to 1800 degrees F. is being applied to the lower portion of the retort with the result that the oil vapors are being driven off and, as the discharge is continuous, this lower portion is being gradually emptied. At the end of three hours the gate between the two portions is opened and the preheated charge from the upper part is allowed to drop into the lower part, the gates are closed, the upper part refilled and the operation is repeated. The spent shale after being discharged is lifted by a bucket chain, sprayed with hot water to remove the potash and then goes to the dump. The educed vapors and gases are condensed and scrubbed as in any process.

The salient points of this process are, (1) the shale is preheated, (2) intermittent feed and continuous discharge, (3) the heat is applied externally the fuel used being the noncondensable gases made in the process, (4) superheated steam is used.

The claim is made that this retort works satisfactorily on both Western and Kentucky shales and the writer sees no reason why it should not do so, in his opinion, the difficulties to be encountered in continuous commercial operation being more apt to be mechanical rather than chemical.

THE STALMAN PROCESS.

This process, developed by Mr. Otto Stalman of Salt Lake City, Utah, embodies a retort of the vertical type. Mr. Stalman for a number of years was connected with the oil shale industry of Scotland and, since interesting himself in the shales of this country, has made extensive tests on those coming from the western states as well as a few tests on Kentucky

shales. According to Mr. Stalman it has been his object to construct a retort which will be easily adapted, by simple modifications, to the successful and profitable treatment of all the western shales and the results obtained, he says, have fully justified expectations.

The retort used is cast of a particular mixture of iron which has been found to resist changing temperatures in the retort oven and which also insures as nearly sound a casting as possible. It has the shape of the frustrum of a cone being 1 foot 6 inches inside measurement at the top or charging end, 2 feet 3 inches at the bottom or discharge end and 18 feet high, the casting being 1.5 inches thick. A tuyere box is placed around the lower portion of the retort so as to allow for the admission of superheated steam to the charge. The top of the retort connects to the charging hopper where the charge is stored and, at the same time, preheated. At the bottom of the retort is an automatic discharging device consisting essentially of a revolving disk. This arrangement not only furnishes an easily regulated and even discharge but, by means of a device connected to it, provides a means whereby the charge may be loosened should it clinker and whereby it may be continuously agitated, if necessary. This precaution insures an even descent of the shale through the retort. In any event the discharge mechanism is so adjusted that the level of the top of the charge is always maintained at the same place and at the same distance below the gas outlet pipe near the top of the retort and this is done in order to avoid carrying off any more dust with the gas and steam into the condensing system than is absolutely necessary.

Charging hopper, retort and automatic discharge are so connected that they are hermetically sealed and air tight gates are provided so that charging and discharging may take place without any interruption of the operation and without the possibility of air entering the retort or gas and steam escaping from it except through the discharge pipe provided for the purpose which pipe is situated near the top of the retort and from whence the gas and steam are led to the condenser.

Four retorts are placed in an oven and as many ovens as necessary to satisfy the capacity desired are built into a bench. The number of retorts required for a given capacity depends entirely on the time necessary for complete distillation of the particular shale being treated and this time will vary, as shown by Mr. Stalman's experiments from four to eight hours. The retort described, then, has a twenty-four hour thruput of nine tons based on a distillation time of four hours. A plant of four ovens or sixteen retorts would, therefore, treat about 150 tons per day but for practical purposes Mr. Stalman says that this size plant should be figured to give 100 tons per 24 hours.

The retorts are charged by a conveyor which carries the shale from the storage bins to the charging hopper, it having been broken, previous to reaching the storage bins, to a maximum size of six inches by a set of spike rolls. It is advised to remove the fine material made in mining and crushing, ¼ inch size and less, before treating and to treat these two classes of material separately. The spent shale drops from the automatic discharge into a storage bin situated beneath the retort and is thence carried by conveyors to the waste dump.

The steam, which enters the retort through the tuyeres previously mentioned, near the bottom of the retort, is taken from the boilers at a pressure of 1.5 lbs. per sq. in. and is superheated during its passage through a series of coiled pipes built in the interior of each oven, before entering the retorts at a temperature of from 600 to 850 degrees F., the most suitable temperature depending on the character of the shale being treated. Suitable baffles, built in the interior of the oven, cause the products of combustion to pass gradually from the bottom of the retort to the top of the oven where they are led off through a chimney.

The products of the retort are hydrocarbon gases, steam with ammonia, and spent shale. The latter is free from oil producing matter and goes to the dump as outlined above. The former products leave the retort together by a branch pipe near the top through which they enter the main gas conduit

common to all the retorts of the unit and are led to the condenser.

This condenser, in this system, is a special, patented device and the products are, as they are with any condenser used for this purpose, gas, crude oil and ammonia water. However, in this system, partial fractionation takes place in the condenser and six classes of oil of different boiling points and specific gravities are made. Each of these six classes of oil together with its ammonia water is then led by short pipe lines to special, individual separators where the ammonia water is separated from the crude oil. From the separators the oil is led through a pipe line to its individual storage tank and from there to the refinery while the ammonia water goes to the ammonia water storage tank for subsequent treatment in the ammonium sulphate plant.

The fixed or fuel gas is withdrawn from the condenser by an exhaust fan which, being in the closed circuit of condenser and retort, aids the passage of the gases through the main gas conduit to the condensers, and then forces them through a scrubber where any ammonia still retained in the gas is extracted by water scrubbing. From the ammonia scrubber the gas, now ammonia free, passes into the gasoline absorption tower where the gasoline, from two to four gallons per thousand cubic feet of gas, contained in it is removed by being absorbed in an oil specifically heavier than gasoline. This oil is then subsequently treated to remove the gasoline. The final permanent gas then goes to a gasometer from which it is withdrawn, as necessary, for fuel purposes.

The ammonia water from both the separators and the ammonia scrubbers is conducted to the ammonium sulphate plant where the ammonia is volatilized and the ammonia gas then led through sulphuric acid the action of the two forming ammonium sulphate which is precipitated out, freed from water, dried and is then ready for the market.

The economic products of the distillation plant are, the crude oil, the gas, the gasoline from the absorption plant and the ammonium sulphate. The latter two are ready for the

market, the gas is used in the plant as a fuel while the crude oil is stored for treatment in the refinery.

According to Mr. Stalman the cost of a plant as outlined above is from $65,000 to $100,000 depending on local conditions and the cost of a 300 ton daily plant for distillation and a Wells System refinery for 400 barrels of crude oil is from $450,000 to $500,000.

The outstanding points about this system are, (1) vertical, continuous retort, (2) heat applied externally, (3) shale not finely crushed, (4) steam used, (5) fractional condensation in a special condenser, (6) maximum production of ammonium sulphate not accomplished.

Mr. Stalman has kindly furnished for the purposes of this paper the following results of tests on both Western and Kentucky shales though it may be said that he has done but little work on the latter.

An average of several lots of Western shale producing about 50 gallons of crude oil per ton with from 15 to 20 lbs. of ammonium sulphate and about 3000 cubic feet of fuel gas, furnished, on refining, the following products ready for the market; gasoline —9%, 460 degrees F. end point; gas oil—29%, 37.7 Be.; motor oil 36%, flash point 375, fire 445, viscosity 106 @ 70 degrees; wax—6%, 130.5 melting point; pitch—10%; loss—10%.

Two charges of 450 lbs. each of Kentucky shale gave, after a four hour treatment at an average temperature of charge of 847 degrees F. at the bottom of the retort and 504 degrees at the top, a yield of 114.5 pounds of oil of a specific gravity at 60 degrees F. of .979 or 13 Be. which figures to 31.2 gallons per ton, the gas obtained amounting to 3,333 cu. ft. per ton and the ammonium sulphate to 4 lbs. per ton. An analysis of the spent shale showed the oil entirely removed.

A test of 460 pounds of a different Kentucky shale gave, after a four-hour treatment at an average temperature of charge of 851 degrees F. at the bottom of the retort and 509 degrees at the top, a yield of 43 lbs. of oil of a specific gravity of .943 or 18 Be., which figures to 23.75 gallons per ton, the

gas obtained amounting to 1,820 cubic feet per ton and the ammonium sulphate to 6.75 pounds per ton.

It is worthy of note that the ammonium sulphate obtained is small and only a small part of that which may be recovered from the average Kentucky shale as, as a rule, these shales run rather high in nitrogen. The explanation of this fact is, undoubtedly, that the maximum temperature used in distillation, less than 900 degrees F., is entirely too low to get an appreciable recovery of ammonia. Therefore, as far as Kentucky shales, at least, are concerned, the Stalman retort should be considered as a producer of oil and not of both oil and ammonium sulphate and if, as, in the writer's opinion, will be the case with Kentucky shales because of their high nitrogen content, a maximum recovery of ammonia is desirable, a subsequent treatment had better be given the spent shale for this purpose.

In the foregoing discussion no attempt has been made to cover all the different processes for recovering oil from shale, but merely to select types to illustrate the different angles at which the problem is being attacked. All of the systems described, with the exception of the one developed by Mr. E. E. Hedges and the writer at the University of Kentucky, have been designed primarily for use with Western shales. The inference is not, however, that those processes and plants developed for Western shales will not work on Kentucky shales, but merely that, in most cases, their applicability to Kentucky shales has yet to be proven.

The value of the unmined crude oil and associated by-products locked within the oil shales of this State is very great. Thinking men are aware that the dawn of the day of shale development is at hand. That American ingenuity will fashion, if it has not already fashioned, the key which will unlock the treasury of oil close held within the Knobs of Kentucky, there can be no doubt. Less spectacular than crude oil from flowing wells, but more so than coal dug from mines, the com-

ing oil shale industry of Kentucky will call into play alertness, aggressiveness and trained intelligence. It offers as rewards great wealth and satisfaction in the ultimate solution of a difficult new industrial problem.

VII

OIL AND GAS POSSIBILITIES OF "THE JACKSON PURCHASE" REGION

By Willard Rouse Jillson,
Director and State Geologist.

LOCATION AND FIELD WORK.

Widely known throughout the lower Mississippi Valley as "The Jackson Purchase" because of the treaty by means of which General Andrew Jackson bought it from the Chickasaw Indians in 1818, that broad, westernmost area of Kentucky which lies beyond the Tennessee River, and includes seven separate counties, has within the last year become a field for somewhat widespread oil and gas prospecting. Though only unfavorable results have been obtained to date, this large portion of the State, containing 2,340[1] square miles, offers an extensive virgin territory for further oil and gas prospecting and development, in the event it can be shown that these mineral resource necessities occur here in commercial quantities.

"The Purchase" region is bounded on the south by 36° 30′ north latitude, and on the north by 37° 15′ north latitude; on the east by 88° west latitude, and on the west by 90° west latitude. Its natural boundaries are principally major waterways: the Tennessee River on the east, the Ohio and Tennessee Rivers on the north, and the Mississippi and Ohio Rivers on the west. The south boundary is the Walker line, which follows with slight deviation the parallel 36° 30′ north latitude from the Tennessee River to the Mississippi River. Its prin-

[1] "The Jackson Purchase" Region, by R. H. Loughridge, Kentucky Geological Survey 1888.

THE MISSISSIPPI RIVER FROM HICKMAN.
The high bluffs at Hickman give one an excellent panorama of the topography of Western Fulton and Hickman Counties in the Purchase Region.

cipal city is Paducah, a town of 24,735 inhabitants,[2] located at the junction of the Tennessee and the Ohio Rivers. Mayfield, Hickman, Murray, Wickliffe, Clinton, and Benton, are county seats of secondary importance, ranking in the order named. The field work on which this report is based was done by the writer personally in June, 1920, during which time a complete reconnaissance of the "Purchase" region was made.

TOPOGRAPHY AND DRAINAGE.

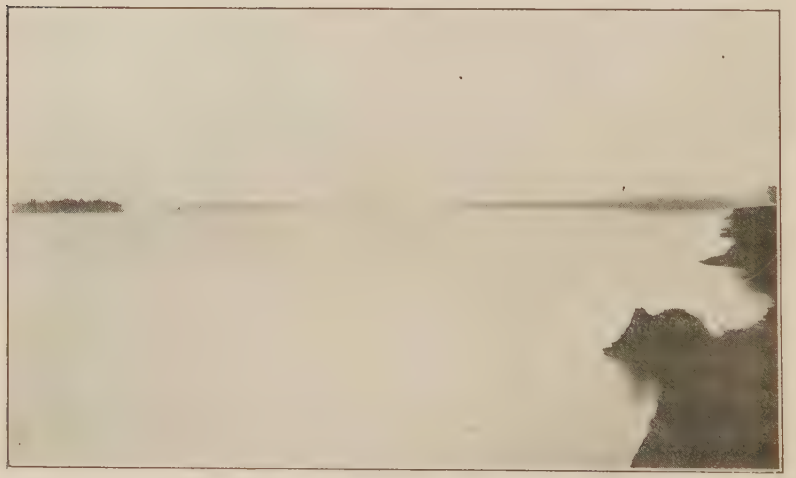
As part of the old Gulf Embayment section of the lower Mississippi Valley, the greater portion of the sediments of which are unconsolidated and at a relatively slight elevation above the present drainage levels of the Mississippi River, the topography of the area considered is uniformly rolling, with little or no sharp configuration, except in the lower courses of the major creeks of the region, or adjoining the Mississippi River. Excellent examples of such rough and broken topography as occur in this section are to be found along Mayfield Creek

[2] 1920 Census.

GEOLOGIC MAP OF THE PURCHASE REGION.

The light areas along the Eastern Border are Mississippian, the dark areas Cretaceous, and the large mottled area Quitternary. The light stippled area along the Mississippi River is Recent in age.

from the McCracken County line to the stream's debouchure into the Mississippi River. This is also true for short distances along the lower portions of Humphrey's and Obion Creeks, and is the principal characteristic along the Mississippi River bluffs from a point some distance north of Wickliffe, south along the east bank of the river, to Hickman and the Tennessee line. These Mississippi River bluffs range in height from 50 to 170 feet, the latter elevations being characteristic of the Hickman section. A very broken topographic figure is the characteristic along the Tennessee River in Calloway and Marshall Counties. The relief here, however, is not as sharp as it is in the west along the Mississippi River. The highest elevation in the Purchase region is a section in the southwestern part of Calloway County, west and southwest of Murray, which is 600 feet above sea level. This region extends northwestward to Linnville, thence lowering gradually it continues northwestward to points west of Mayfield, which attain elevations of 450 and 500 feet. As a topographic high it extends southward from the vicinity of Crossland into Henry



MOUTH OF THE OHIO RIVER.

Standing out on the lowest flood plain west of Wickliffe in Ballard County one sees the juncture of the Ohio and Mississippi Rivers. On the right the low Recent flood plain can be seen merging into the higher plateau of Quaternary age.

County, Tennessee, where it attains its broadest figure as a plateau. This broad upland is surrounded by two undulating plateau regions showing elevations between 450 and 500 feet. Low water at Paducah is 286 feet, and the city has an altitude of 341 feet. The lowest point within this area is found at low water in the Mississippi River, at the Kentucky-Tennessee line, which is about 245 feet, the elevation of low water, at Hickman, being 256 feet.

The major drainage of the Purchase region bounds it on three sides, and consists of the Tennessee, Ohio and Mississippi Rivers, to which all interior drainage is tributary. The smaller drainage in Calloway, Marshall, eastern McCracken, and northern and eastern Graves Counties, consists of Blood River, Jonathan Creek, and Clark's river, all of which flow to the north and are tributaries to the Tennessee River. Western McCracken County, through Massac Creek and Spring Bayou, drains directly into the Ohio River. Ballard County, in the northern portion, is drained by Humphreys Creek, and in its central portion is drained by Mayfield Creek, the largest of the interior drainage units. Hickman and Fulton are drained principally by Obion Creek and Bayou de Chien, which are tributaries to the Mississippi River just above Hickman townsite. These latter streams find their headwaters in southern Graves County.

REGION OF OLD GULF EMBAYMENT.

The straight dark lined area at the east of the Mississippi River is Cretaceous, the light dotted area at the west and south is Recent. The head of the old Gulf near Cairo and Paducah is well shown.

STRATIGRAPHY.

The surficial rocks of the area considered consist of limestones, sands, clays, and gravels, that range in age from the Mississippian to Recent. The record is not one, however, of continuous and unbroken sedimentation. With the exception of the Mississippian limestones which are found exposed in the lower drainage courses of the creeks emptying into the Tennessee River in Calloway and Marshall Counties, the sedimentary deposits of the "Purchase" region are practically all soft or unconsolidated. Occasionally, however, ferruginous sandstones or conglomerates of a dark brown iron color, locally called "iron-stones," may be seen in outcrop at the surface, or found by the prospecting bit. These hard sandstones are, however, simply iron cemented lenses of small and irregular figure which may occur in any sand horizon where a downward percolation of the iron containing waters is temporarily arrested by an underlying impervious stratum of clay. These "iron-stones" are, therefore, not continuous in their extent, and are hence considered as unconsolidated sediments.

The several geological formations recognized in the sequence of the embayment sediments, and presented in their order of super-position, are: the "Eutaw" sand, "Selma" clay, Ripley sands and clays, all of which belong to the Cretaceous; the Porters Creek clays, and the Lagrange sandstones, which are Eocene; the "Lafayette" sands and gravels of the Pliocene; the "Columbia" sand and loess of the Pleistocene; and the stream and river alluvium of Recent and Present age. All of these sediments in the order as given, though in varying thicknesses, due to the nature of their deposits, are supported by the older Mississippian limestones which completely underlie the area. These latter consolidated sediments are spoken of in the literature as forming a part of the Paleozoic floor or bench underlying the embayment deposits of the old Gulf, which found its head in Cretaceous times in the vicinity of Cairo, Ill.*

*Upper Cretaceous Floras of the Eastern Gulf Region in Tennessee, Mississippi, Alabama, and Georgia. E. W. Berry, U. S. Geo. S. Prof., p. 112, 1919.

HILLMAN FERRY OVER THE TENNESSEE RIVER.

On the right may be seen the steep high cliffs of the hard Mississippian Limestones of Lyon County, and on the left which is west the characteristically low plateau of Marshall County and the Purchase Region generally.

PALEOZOIC ROCKS.

The lithological characteristic, structural figure, and stratigraphic sequence of the several formations comprising the Paleozoic series underlying the "Jackson Purchase" region has long been a matter of much interest and speculation to artesian water and oil and gas prospectors. Unfortunately, due to the rapid thickening of the embayment deposits (Cretaceous, Tertiary, Recent), and the almost complete blanketing of these older Paleozoic consolidated sediments, little has been known until recently of the structural configuration of the Mississippian and lower formations beneath this area. In the progress of recent oil well drilling in Fulton County, Kentucky, and Obion and Lake Counties, Tennessee, in the section adjoining Reel Foot Lake, the Mississippian limestones have within the last month or so been encountered at greater depth than ever before experienced in this broad region. Calculations based on these discoveries allow an interesting interpretation of the structural figure assumed by the Paleozoic floor.

Structure.

Where the Mississippian limestones go under the cover of Cretaceous sediments on the eastern side of the "Purchase" region they are found to be dipping at the rate of between 25 and 30 feet to the mile. This rate of dip, if projected across the "Purchase" region to the Reel Foot Lake section, would place the top of the Mississippian limestone in the Reel Foot Lake section at about 2,000 to 2,100 feet below the surface there. It is interesting in this connection to note that the well now being drilled at Bondrant Station, on the C. M. & G. Railroad, 8 miles southwest of Hickman, and one mile north of Reel Foot Lake, in Fulton County, Kentucky, by Roney-Mitchell-Bruer, encountered the Mississippian limestone at a depth ranging between 2,270 and 2,300 feet, the exact point of which has not been accurately determined, due to inability to examine the drill cuttings.

The slight difference between the computed depth of the Mississippian limestone and the actual depth at which it was

QUATERNARY GRAVELS OF THE PURCHASE REGION.
These gravels, frequently iron stained and cemented, form the surficial sediments of large portions of Marshall and Calloway Counties and are used to good advantage in road construction especially in low or boggy creek bottoms.

found may be disregarded, since the difference between the topographic elevation of the point of disappearance of the limestone in the east and the casing head elevation of the well might easily offset this error. Under the City of Paducah the Mississippian limestone was found in an old gas well drilled in 1888[3] at a depth of 335 feet. At La Center on the I. C. Railroad in central Ballard County, Kentucky, the Mississippian chert was found at 387 feet,[4] which depth would indicate that the consolidated limestones of the Mississippian would occur at about 400 feet at the same point. At Wickliffe, in Ballard County, Kentucky, a well is reported to have entered the Mississippian limestone at a depth of 1,000 feet. The configuration of the Paleozoic floor as based on this data, represents it as a great subsurface plane gradually sloping to the southwest. The dip would be almost due west from Murray, southwest

[3] "Jackson Purchase," by Loughridge, Kentucky Geological Survey, 1888.
[4] Underground Waters of Tennessee and Kentucky, W-S. Paper, No. 164, L. C. Glenn, 1906, p 22.

from Paducah, and slightly west of south from Wickliffe, Kentucky, or Cairo, Ill. As to the uniformity of the dip, no positive statement can be made, but there is reason to believe that it is not uniform, even in a general way. Flatter dips in the vicinity of the Mississippi River in Carlisle, Hickman and Fulton Counties may be reasonably inferred as the natural resultant of a line of semi-concentric scarping following geographic configuration of the Ohio and Tennessee Rivers, and extending southwestward from the middle of Ballard County, through Graves and into eastern Weakley County, Tennessee. Support to such a theory is given by the records of wells drilled at La Center and Wickliffe in Ballard County. The lack of a strictly uniform dip is proven by the occurrence of the Mississippian limestone in the Bondrant well at slightly greater depth than calculated from the observed dips along the eastern outcrop.

The sequence of the Mississippian and Devonian sediments that might be expected to be encountered underneath the "Purchase" region is based upon the observations of the clos-

A RUSTIC HOME IN MARSHALL COUNTY.

The log cabin county home with "stick an' mud" chimney is frequently seen in the hilly parts of Marshall and Calloway Counties in the eastern part of the Purchase Region. Happiness and contentment generally abides within.

est outcrops in the area surrounding to the north and east in Kentucky and Illinois, and is as follows:

GEOLOGICAL SECTION OF PENNSYLVANIAN, MISSISSIPPIAN & DEVONIAN SEDIMENTS COMPUTED FROM OUTCROP OBSERVATIONS IN WESTERN KENTUCKY & SOUTHERN ILLINOIS FOR THE JACKSON PURCHASE REGION OF KENTUCKY.

Pennsylvanian System.

Pottsville Series (basal).

Trade Water Formation.[1]

Shale and sandstone with two thin coal seams and a six-inch layer of yellow limestone. Much of the sandstone is more or less massively bedded, coarse, friable and felspathic. Full thickness of the formation 594 feet.

Caseyville Formation.[1]

Conglomerate, sandstone and shale, the pebbles of the conglomerate beds being of white quartz, smoothly rounded. In places a two-foot bed of coal is present about 125 feet from the top of the formation. Full thickness about 400 feet.

Great Unconformity.

Mississippian System.[2]

Chester Series.

Kinkaid Limestone.

Interbedded limestone and shale. The limestone beds commonly one foot more or less in thickness, the shale beds from a few inches to several feet in thickness. The limestone is variable in character, gray to blue or almost black in color, mostly hard and compact, with little or no crystalline members. A thin sandstone member is present in places, and locally there are massive chert beds in the lower portions of the formation. Maximum thickness about 180 feet.

Degonia Sandstone.

Yellowish brown sandstone, perhaps lighter colored under cover, varying from massively bedded to thinly bedded or even arenaceous shales in places. Thickness ranging from 30 to 100 feet.

Clore Limestone.

Lithologic character exceedingly variable in character, in places nearly all shale with thin limestone beds, elsewhere with more limestone which is commonly noncrystalline, and rather hard and compact in texture. Thickness about 40 feet.

[1]These Pennsylvanian formations may occur locally under the Cretaceous of the Purchase Region of Kentucky due to fauling. They are not widely distributed, however.

[2]The divisions made follow the interpretations of Stuart Weller.

Palestine Sandstone.

Rather fine grained, yellowish brown sandstone, in places with a pinkish tint. Bedding varying from massive to thin with small arenaceous shale layers locally. Thickness 50 to 100 feet.

PANORAMA IN HICKMAN COUNTY.

The gently undulating figure of the topography in the vicinity of Clinton is well illustrated in this view five miles south of Clinton.

Menard Limestone.

Mostly hard, compact limestone, gray, blue to almost black in color, slightly or noncrystalline, in layers one foot, more or less, in thickness, separated by shale beds from a few inches to several feet in thickness. A much greater amount of shale is commonly present in the lower portion of the formation, with more massive limestone beds in the higher portion. A small amount of chert may be present. Thickness 80 to 120 feet.

Waltersburg Sandstone.

Sandstone variable in character, from very massive, cliff-making beds to thinly bedded layers, which break up into sliver-like fragments. Much of the sandstone is yellowish to brown in color, but where the formation is thin the fresh beds are nearly black in some places. Much dark, sandy shale is associated with the sandstone in places. Thickness 10 to 60 feet.

Vienna Limestone.

An exceedingly silicious limestone below with much chert in thin layers in surface outcrops, passing into dark carbonaceous, or gray clay shales above. Thickness 40 to 60 feet.

Tar Springs Sandstone.

A formation made up of several more or less massive beds of sandstone separated by more shaly members. The sandstones vary from white to yellowish brown in color, and are commonly rather fine texture. The shale members are arenaceous or argillaceous in character, and an impure coal seam from an inch or two to two feet in thickness is a rather persistent member of the middle portion of the formation. Thickness from 40 to not more than 200 feet.

MIDDLE CHESTER GROUP.

Glen Dean Limestone.

Varying proportions of limestone and shale. Limestone beds commonly more or less crystalline, locally oolitic in texture, gray to blue in color. The shale beds variable in character, commonly blue or nearly black to gray in color, and argillaceous in composition. The formation may be comprised almost exclusively of limestone, or it may be nearly all shale, the changes in character being very abrupt in places. Thickness 30 to 70 feet.

Hardinsburg Sandstone.

Rather fine grained, yellowish brown sandstone in thick or thin beds. In places the formation includes a notable arenaceous shale member in its middle portion. Thickness 25 to 100 feet.

Golconda Limestone.

Limestone and shale in varying proportions. The limestone beds are exceedingly variable in character, but are commonly gray to dark blue in color, and more or less crystalline. In places there are notable beds of white oolite. Fossils are abundant with many bryozoans and crinoid stones. Some beds of more compact, noncrystalline limestone may be present. The shales are also variable in character, black, gray, and in places red in color, mostly agrillaceous, but somewhat arenaceous shales may be present locally, especially in the lower portion of the formation. The proportions of limestone and shale vary greatly. In places 50% or more of the formation may be limestone, elsewhere less than 10%. Thickness from 30 to 175 feet.

Cypress Sandstone.

Yellowish brown, rather fine textured sandstone, in massive or thin beds. Commonly without shale partings. Thickness 30 to 110 feet.

LOWER CHESTER GROUP.

Paint Creek Limestone.

A limestone and shale formation exceedingly variable in character. The limestone is commonly gray to white in color, and is crystalline, oolitic or compact in texture, some beds very argillaceous. In places nearly the whole of the formation is fissile black or greenish shale. Elsewhere it is almost wholly limestone. In the typical locality in southwestern Illinois there is a notable deep-red clay or shale bed. Thickness 40 to 100 feet.

Bethel Sandstone.

Massive to thin-bedded sandstone, moderately fine in texture, yellowish brown in color. Similar in character to the Cypress sandstone. Represented in the Mississippi Valley sections by a more or less quartzitic chert bed, the Yankeetown chert. Thickness 10 to 100 feet.

Renault Limestone.

A limestone and shale formation in the Ohio valley, but including some sandstone members in the Mississippi River sections. The limestones variable in character, commonly blue to gray in color, crystalline or compact in texture, in places with considerable oolite. The shales commonly gray in color, thinner than the limestone portions of the formation. Thickness about 100 feet.

Aux Vases Sandstone.

This formation is wanting in the Ohio valley. It is a yellowish brown, fine textured sandstone similar to other sandstones of the Chester Series. Thickness 0 to 80 feet.

IOWA SERIES.

Meramec Group.

St. Genevieve Limestone.

Mostly light colored, oolitic limestones, with some darker beds of more or less compact or crystalline limestone, and some minor shale partings. In the upper portion of the formation a very persistent sandstone member, the Rosiclaire sandstone, from 20 to 25 feet thick, is present. Thickness 150 to 200 feet.

St. Louis Limestone.

Bluish gray to black, compact, more or less silicious limestone, not known to be oolitic. Thickness 350 feet.

Spergen or Salem Limestone.

Light colored oolitic or crystalline limestone, in most places non-silicious. Thickness 150 feet.

Warsaw Limestone.

More or less impure shaly limestone, somewhat silicious. Mostly dark gray to blue in color, and more or less crystalline in texture. The shale beds argillaceous and more or less silicious. Thickness 50 to 100 feet.

Osage Group.

Keokuk and Burlington Limestones.

Light colored, crystalline limestone with great quantities of chert. In places the chert contributes 50% or more of the contents of certain beds. Thickness 200 to 500 feet.

Kenderhook Group.

This basal group of the Iowa Series of the Mississippian is not well developed in the Ohio Valley. It is likely to be comprised of a variable series of beds, perhaps comprising limestones, sandstones and shales. Its thickness is probably not great, perhaps 50 feet, and probably even thinner than this.

Devonian.

Chattanooga Shale.

Black, more or less fissle, carbonaceous shale. Thickness 400 feet in Hardin County, Illinois.

Devonian Limestone.

Beneath the Chattanooga shales is a series of Devonian limestones which must represent the Grand Tower limestone of southern Illinois, Middle Devonian in age, and beneath these other limestones of lower Devonian age, some of which may be highly silicious. The thickness of these limestones is uncertain, but is probably 350 feet or more.

New Madrid Earthquake.

No discussion of the oil and gas possibilities of the "Purchase" region of Kentucky would be complete without an evaluation of the probable effects of the New Madrid Earthquake of 1811, and other associated earth tremors of earlier and subsequent date. While the fullest and most detailed studies and observations of such great seismic disturbances as those which it is known involved this and the much larger surrounding area of unconsolidated sediments, can never fully reveal the actual extent of structural deformation at such depths as must necessarily be included in this oil and gas consideration, there is, nevertheless, much to be gleaned of an instructive nature. In looking into the causes of that long series of seismic disturbances, including the New Madrid earthquake and later tremors, which have affected that area under discussion, causal factors of importance once placed in the unconsolidated sediments of the embayment sequence have now been thrown out.

It is now recognized that the real cause of these earth disturbances found their origin in the regional readjustments of the rocks composing the Paleozoic floor and its underlying and older sequence.[5] Such constructions predicate necessarily extended faulting of the consolidated rocks of this and adjoining regions generally. This assumption is rendered the more reasonable since it is known that many of the faults which mark the Mississippian scarp on the eastern side of the Tennessee River pass across this river and into the "Purchase" region.

[5]The New Madrid Earthquake, Bulletin No. 494, U. S. G. S., M. L. Fuller, 1912, p. 104.

It has been suspected by Loughridge[6] that faulting to the extent of a displacement of about 1,300 feet has taken place in the Paleozoic sediments underlying the City of Paducah. There is some further confirmation of this interpretation of the sub-surface conditions in the northern part of the "Purchase" region to be secured from a detailed knowledge of the sharp block faulting of western Livingston County, Kentucky, which if projected to the southwest would pass under the City of Paducah, and very possibly give the figure of displacement suggested. Such known disturbances as these must reasonably be associated with many others of a similar and lesser scale which are completely obscured by the unconsolidated sediments found at the surface in the "Purchase" region. How far within the "Purchase" from the northwest the intensely faulted section of the consolidated rocks of the Mississippian and sub-adjacent Systems extend toward the Reel Foot Lake section, it is of course impossible to say; but that the entire region is more or less faulted appears to be without doubt the actual condition.

The disturbances of the New Madrid and other earthquakes throughout this portion of the Mississippi Valley were without doubt associated with the lines of old structure and faulting, though it is true that the surficial features observed cannot be said to have had this direct cause. In this connection it is not supposed that the domed area south of and adjoining the Reel Foot Lake section which has been responsible for the damming up of the waters of the creek which formerly occupied this area, is anything more than an expression of compression forces operating entirely within the embayment deposits themselves. It is quite impossible to associate the doming of consolidated rocks such as form the Paleozoic floor of this region with this surficial anticlinal expression, since it is known definitely that the faulting or arching of thoroughly indurated sediments is only accomplished through very long periods of geologic time. In the same category must be regarded the

[6]Jackson Purchase Report, Loughridge, Kentucky Geological Survey, 1888, p. 320.

A MARSHALL COUNTY PANORAMA.
Benton the County seat is in the middle background and the valley is that of the East Fork of Clarkes River. Characteristic Eastern Purchase Region topography.

many small faults which were noticed by various observers in the region to have occurred during the time of, or shortly following, the earthquake disturbances. Without doubt these surficial structural features represent only the adjustment of unconsolidated sediments whose mass has been set in motion after a long period of tension by the disturbances indigenous to the consolidated rocks of the Paleozoic base below them.

Results of Drillings.

A large number of wells have been drilled in the "Purchase" region for artesian water, most of which have gone only to depths of a few hundred feet, and are therefore practically useless in this consideration, since no oil or gas in commercial quantities may be expected in this whole region at such shallow depths. A few water wells such as the La Center and Wickliffe wells are of importance, since they give the depth at which consolidated sediments, in which oil and gas reservoiring sands may be contained, are found. The records of the wells now drilling, or recently completed, in oil and gas prospecting in Fulton County, Kentucky, and Obion and Lake Counties, Tennessee, are of the very greatest importance in interpreting the drilling section for the entire region, and affording information as to possible "sands," and the depths at which they might be reasonably expected at adjacent or more distant points.

The Bondrant well has shown conclusively that little indeed may be expected in the way of commercial oil and gas above 2,000 to 2,100 feet in depth in the vicinity of western Fulton County, since no thoroughly consolidated rocks which might serve as containing reservoirs for oil and gas were encountered above the Paleozoic limestones of Mississippian age. Using the information as given by the Bondrant well, which has now attained a depth of 2,645 feet, future prospecting in the "Purchase" region may well be guided as to depths and as to "sands" with great commercial advantage. Drilling records of this and several wells in McCracken, Ballard and Fulton Counties, Kentucky, are given herewith in detail, their actual

THE FULTON WELL.

It was drilled about a quarter of a mile north of the Tennessee line and just east of Fulton, Ky. A standard rig was used and the well was started with a regulation steel bit. This had to be abandoned later and rotary drilling instituted, because of the soft nature of the sediments.

sequence of sediments being interpreted stratigraphically as closely as the samples or the record would allow.

BALLARD COUNTY, KENTUCKY.

Log No. 1.

Log of Illinois Central Railroad well.[7]
Location: La Center, Ballard Co., Ky.

Strata			Thickness	Depth
Quaternary System				
Clay (loess, loam)			20	20
Tertiary System				
Sand and clay	(Lafayette)	Pliocene	18	38
Cement gravel			38	76
Sandy clay	(Lagrange)	Eocene	34	110
Marl and streaks of sand			28	138
Gumbo (Porters Creek)			112	250
Cretaceous System				
White sand	(Ripley)		5	255
Brown sand and clay			132	387
Mississippian System				
Limestone			10	397
Gumbo and "Elco" gravel, mixed	(Mississippian)		48	445
Brown sand and clay			113	558

Log No. 2.

Log of well in southern part of Wickliffe, Ballard Co., Ky.[8]

Strata			Thickness	Depth
Quaternary System				
Yellow clay and gravel			12	12
Tertiary System				
Potter's clay	(Lagrange)	Eocene	130	142
Coarse sand, clear, yellowish, or reddish			300	442
Blue marl or soapstone (Porters Creek)			158	600
Cretaceous System				
Soft sand, water bearing	(Ripley)		10	610
Blue marl with some kaolin, down to 1,000 feet depth			390	1,000
Mississippian System				
Flinty limestone (penetrated)			20	1,020

[7]W-S. & Irrigation Paper, No. 164, p. 124, Underground Waters of Tennessee and Kentucky, by L. C. Glenn, 1906.
[8]W-S. & Irrigation Paper, No. 164, p. 124, Underground Waters of Tennessee and Kentucky, by L. C. Glenn, 1906.

FULTON COUNTY, KENTUCKY.

Log No. 3.

Roney, Mitchell & Bruer, Hickman, Ky., owners and operators.

Location: 150 yds. S. E. Bondrant Station on C. M. & G. R. R., which is 8 miles S. W. Hickman, 1 mile N. Reelfoot Lake.

Drilled with rotary machine.

Driller, De Orman.

Authority: J. W. Roney.

Incomplete record; well to be drilled deeper.

Strata		Thickness	Depth
Quaternary System			
Soil		15	15
Sand		105	120
Clay		15	135
Tertiary System			
Sand	Pliocene or Miocene	20	155
Gumbo	Pliocene or Miocene	95	250
Gumbo and gravel, (10 in. casing)	Lagrange	50	300
Sand and gravel	Lagrange	50	350
Sand, brown	Lagrange	100	450
Sand, hard	Lagrange	480	930
Sand rock	Lagrange	70	1,000
Brown water sand	Lagrange	100	1,100
Sand, hard	Lagrange	240	1,340
Shale, black, and gumbo, (8 in. casing)	Porter's Creek	105	1,445
Brown rock (gas show)	Porter's Creek	6	1,451
Black Gumbo	Porter's Creek	369	1,820
Cretaceous System			
Shale, hard, and hard sand and gravel, showing some oil and gas all the way	Ripley (McNairy and Selma)	94	1,914
Shale, hard, and sand	Ripley (McNairy and Selma)	71	1,985
Limestone, hard, gray, with layers of chalk	Ripley (McNairy and Selma)	285	2,270
Strata			
Mississippian System			
Limestone, hard, gray (6-in. casing)		130	2,400
Limestone, hard, brown, green and red		300	2,700
Limestone, hard, black, pyrites and silica		200	2,900
Chalk rock, white		50	2,950
Limestone, hard, gray, sand and brown shale (oil show)		230	3,180
Incomplete depth, Dec. 7, 1921.			3,180

NOTE: The computed thickness of the entire Mississippian Series regarded as present beneath the embayment series has been placed at from 1,800 to 2,300 feet. Accepting the base of the Cretaceous as 2,120 the base of the Missssippian and the top of the Devonian here is probably about 4,300 feet below the surface. For purposes of comparison in this little "wild catted" section of extreme western Kentucky, the record of three recent wells, all drilled near to Reelfoot Lake, in Obion and Lake Counties, Tenn., are given as follows:

LAKE COUNTY, TENNESSEE.

Log No. 4.

Reelfoot Dome Oil Co., lessor.

Location: Northwest side of Reelfoot Lake, at Proctor City.

Authority: De Armand, driller.

Strata		Thickness	Depth
Quaternary System			
Soil		10	10
Sand and gravel		135	145
Unknown, (no sample)		55	190
Clay, blue gray, sticky		20	210
Sand and clay, like buttermilk, with wood, some reddish		15	225
Tertiary System			
Quicksand		75	300
Sand, blue, little clay		80	380
Sand, gray		103	483
Sand		45	528
Gumbo		37	565
Sand, hard		20	585
Sand, brown, coarse		200	785
Sand, hard, and gravel	Lagrange	115	900
Sand rock		50	950
Shale, black		70	1,020
Sand, hard, coarse		60	1,080
Gumbo, gray		60	1,140
Sand, brown, coarse		125	1,265
Gumbo, sandy		210	1,475
Shale, black		25	1,500
Gumbo, sandy, (show of oil)		80	1,580
Shale, black	Porter's Creek	20	1,600
Shale, hard, yellow, fine shells		20	1,620
Gumbo, sandy		30	1,650
Cretaceous System			
Shale, black, with blue lime shells and white flint		70	1,720
Shale, blue, with hard shells of flint and pyrite	Selma—McNairy and Ripley	230	1,950
Shells and hard sandstone		24	1,974
Limerock		101	2,075
Total depth			2,075

Note: Stratigraphic division by W. A. Nelson, State Geologist, Tennessee Geological Survey. Selma fossils found in bottom of well.

OBION COUNTY, TENNESSEE.

Log No. 5.

Roger Well, No. 1, lessor.

Reelfoot Ranger Oil Co., lessee.

Location: 3 miles east of Walnut Log, in Obion County, Tennessee.

Collaborated authorities: J. S. Hudnall, collector of cuttings from Tennessee Geological Survey, and C. H. Richardson, mineralogical and lithological examinations. This log compiled from actual cuttings of rotary drill.

Strata		Thickness	Depth
Quaternary System			
Clay, calcareous, yellowish gray		70	70
Clay, ferruginous		20	90
Clay, calcareous, yellow		10	100
Tertiary System			
Gravel, coarse, river water rounded		40	140
Sand and gravel, river water rounded and fine		5	145
Gravel, coarse, ferruginous		10	155
Unknown (no sample collected)		145	300
Sand, silicious, fine, gray,		25	325
Sand or shale, fine, light gray		5	330
Sand, dolomitic and calcareous, and shale		25	355
Unknown		5	360
Shale, dolomitic, manganiferous and carbonaceous		30	390
Sand, fine, with carbonaceous matter		20	410
Gravel, fine, light gray		25	435
Sand and gravel (break), angular, carbonaceous		30	465
Sand, fine, and gravel, light gray	Lagrange	30	495
Sand, fine, and gravel, light gray		45	540
Gravel, ferruginous, coarse		30	570
Sand, mostly white, fine		5	575
Sand and gravel		10	585
Shale, light colored, fine quartz sand		15	600
Sand with little gravel, fine, and shale		20	620
Sand and gravel, slightly dolomitic, mollusca		25	645
Sand, coarse, subangular (break)		10	655
Sand, shale and gravel, small fossil		25	680
Sand, shale and flat limonite gravel		70	750

		Thickness	Depth
Sand and gravel, coarse and fine	Lagrange	20	770
Sandstone, fine and coarse		100	870
Sand and gravel, some clay		30	900
Sand, white, and ferruginous gravel		10	910
Sand, mostly white		10	920
Sand and gravel, flat and angular, pea size		30	950
Gravel, ferruginous, (break), some sand		115	1,065
Unrecorded		140	1,205
Sand and gravel	Porter's Creek	20	1,225
Gravel and clay		10	1,235
Sand and gravel, coarse		40	1,275
Sand and gravel and clay		45	1,320
Sand, gravel, sand clear quartz		120	1,440
Sand, gravel, mostly clear quartz sand		45	1,485
Sand, quartz and gravel of sandstone		20	1,505
Sand and gravel, mostly white quartz		95	1,600
Sand, very fine		25	1,625
Sand and gravel, shaly		60	1,685
Sand, gravel and bluish shale		40	1,725
Shale, bluish gray, alumina and silica		15	1,740
Total depth			1,740

Note: There was no showing of oil in any of the above drill cuttings. "This well started on top of loess bluff and ended at 1,645 instead of 1,745, according to statement of Will Morris, one of the drillers. It finished in Porter's Creek clay of Tertiary age." W. A. Nelson, State Geologist of Tenn. If the driller's statement is true, and there is an error of 100 feet in the record, either footage may occur at the "unrecorded" 140 feet above 1,205, or "no sample" 145 feet above 300 feet in depth.

OBION COUNTY, TENNESSEE.

Log No. 6.

O. T. Wallaston, No. 1, lessor.

Reelfoot Ranger Oil Co., lessee.

Location: Walnut Log, Obion County, Tennessee.

Strata	Thickness	Depth
Quaternary System		
Surface soil	3	3
Clay, silt and sand	17	20
Quicksand	70	90
Gravel, river water worn	95	185
Clay, silt and sand	10	195
Sand, (water)	20	215

Tertiary System		Thickness	Depth
Gravel, clay and artesian flow		30	260
Clay		15	275
Sand and clay		20	295
Sand, clay and rock		5	300
Sand and clay		10	310
Sand and gravel		20	330
Quicksand		5	335
Gravel		5	340
Gravel and sand		5	345
Sand and clay		25	370
Sand and gravel		40	410
Gravel, sand, flint, chalk rock		20	430
Clay, blue, fine, sticky		19	449
Sand and flint		31	480
Gravel		91	571
Clay, sticky, and sand	Lagrange	29	600
Gravel and sand		40	640
Clay, sticky, and sand		15	655
Sand		65	720
Sandstone, hard, some gas		5	725
Gumbo and sand		45	770
Sand		10	780
Sand and gumbo		20	800
Sand		40	840
Sand and gumbo		15	855
Sand, (asphalt)		5	860
Clay, sticky, and sand		65	925
Sand		30	955
Clay, fine, and sand		20	975
Sand		35	1,010
Clay, sticky, and sand		65	1,075
Total depth			1,075

Log No. 7.

Terry, No. 1, lessor

Fulton Oil & Gas Co., lessee.

Location: ½ mile east of Fulton and ½ north of Ky.-Tenn. line.

Authority: B. L. Andrews, Fulton, Ky.

Strata	Thickness	Depth
Quaternary System		
Soil and clay	80	80
Clay and sand	35	115
Clay and sand	20	135
Tertiary System		
Water sand, (good head water)	15	150
Clay	20	170
Sand, fine	20	190
Sand, fine	10	200
Sandy muck	40	240
Sand, very fine	10	250
Incomplete depth		250

15 in. casing set 60 feet.

12½ in. casing set 240 feet.

10 in. casing on ground to go 1,000 feet.

Will change to rotary drill soon.

McCRACKEN COUNTY.

Log No. 8.

Paducah Well.

Lessor unknown.

Lessee unknown.

Location: Within the city of Paducah.

Drilling completed in 1888.

Production: Dry.

Drilling samples collected by J. C. Farley and W. L. Bradshaw.

Authority: R. H. Loughridge, Ass't Geologist, Jackson Purchase Report of Kentucky Geological Survey, Series II, p. 321-326, pub. 1888.

Strata	Thickness	Depth
Quaternary System		
Loam, brown, micaceous	40	40
Gravel, rounded chert and quartz	20	60
Tertiary System		
Clay, black, and sand	90	150
Cretaceous System		
Clay and sand, micaceous, interlaminated	114	264
Chert, quartz, and pyrite debris	71	335

		Thickness	Depth
Mississippian System			
Limestone, shaly, white, fossils	Chester Group	90	425
Limestone, dark, impure, cavernous	Chester Group	45	470
Limestone, silicious, cavernous	Chester Group	48	518
Shale, dark, limy, fossils	Chester Group	32	550
Shale, white, limy, fossils	Chester Group	185	735
Limestone, blue, Pentremital	Chester Group	400	1,135
Limestone, blue, fractured, loose sand	(St. Louis)	115	1,250
Total depth			1,250

SUMMARY OF OIL AND GAS POSSIBILITIES.

A review of all the information now obtainable concerning the surficial and sub-surface geology of the "Jackson Purchase" region, allows the citation of the following points as having direct bearing on the possibilities of securing commercial quantities of oil and gas in this region: (1) All drilling completed to date has shown the sequence of unconsolidated embayment deposits in this region to be unproductive of commercial quantities of oil and gas. (2) Drilling depths to consolidated Mississippian limestones will vary from "0" on the outcrop, to about 2,270 feet in this section of Kentucky. (3) A thickness of from 1,800 to 2,300 feet may be expected to be encountered in the Mississippian limestones. (4) A thickness of from 100 to 200 feet may be expected to be encountered in the Devonian shales and limestones. (5) Well drilling to deeper "sands" than those of the Silurian is not recommended, though it is recognized that production might, as a remote possibility, be found. (6) Surficial structural figures such as anticlines, domes, faults, etc., as seen in the unconsolidated sediments of this region, may not be regarded as valuable or accurate criterions concerning the deformation of the Mississippian and lower rocks of the Paleozoic. (7) The sub-surface structure of the Paleozoic floor under the "Purchase" region is undoubtedly considerably faulted, the extent of which it is not possible to determine. (8) Associated with the sub-surface faulting of the "Purchase" region there occurs undoubtedly a certain degree of folding expressed in monoclinal, anticlinal and synclinal

LOWER REACHES OF MAYFIELD CREEK.

As it nears the Mississippi River in Carlisle County, this stream becomes sluggish and suffers from backwater during the Summer. It is flanked on either side by rather high bluffs of clays and gravels throughout this lower region.

figures, the exact location of which it is impossible to determine by surface observations. These structures may eventually be located by well drilling and the accurate plotting with casing head elevations of carefully kept records of all wells drilled. (9) In the present stage of oil and gas development of the "Purchase Region," no better method for oil and gas prospectors to go by than straight "wildcatting" is recognized. (10) All such "wildcatting" operations as may be undertaken in the future and their results, coupled with the well records of wells already drilled, when carefully studied, will serve as guides in selecting the locality and anticipating the general drilling conditions which may be expected to be encountered. (11) No close or reasonable connection is regarded as possible between the geology of the spectacular "Eldorado" oil field about 300 miles southwest, in Arkansas, and on the west side of the Mississippi River, and the geology known to obtain within the "Jackson Purchase" region of Kentucky.

VIII

OIL AND GAS POSSIBILITIES IN CALDWELL COUNTY, KENTUCKY.

By Stuart Weller.
Assistant Geologist.

INTRODUCTION.

During the progress of the detailed mapping of the geology in the Princeton, Kentucky Quadrangle of the U. S. Geological Survey atlas sheet, in the summer of 1921, the greater portion of which falls within Caldwell County, an area which may possibly be productive of oil and gas has been discovered. At the present time there is no oil or gas production in the County; a few wells have been drilled, one of which, a dry hole, has just been completed to a depth of 2,000 feet at Cedar Hill, two and one-half miles southeast of Princeton. A number of wells have been drilled in the past, one or two of which are reputed to have shown a trace of oil, but no definite record of them can be secured at this time.

THE FARMERSVILLE DOME.

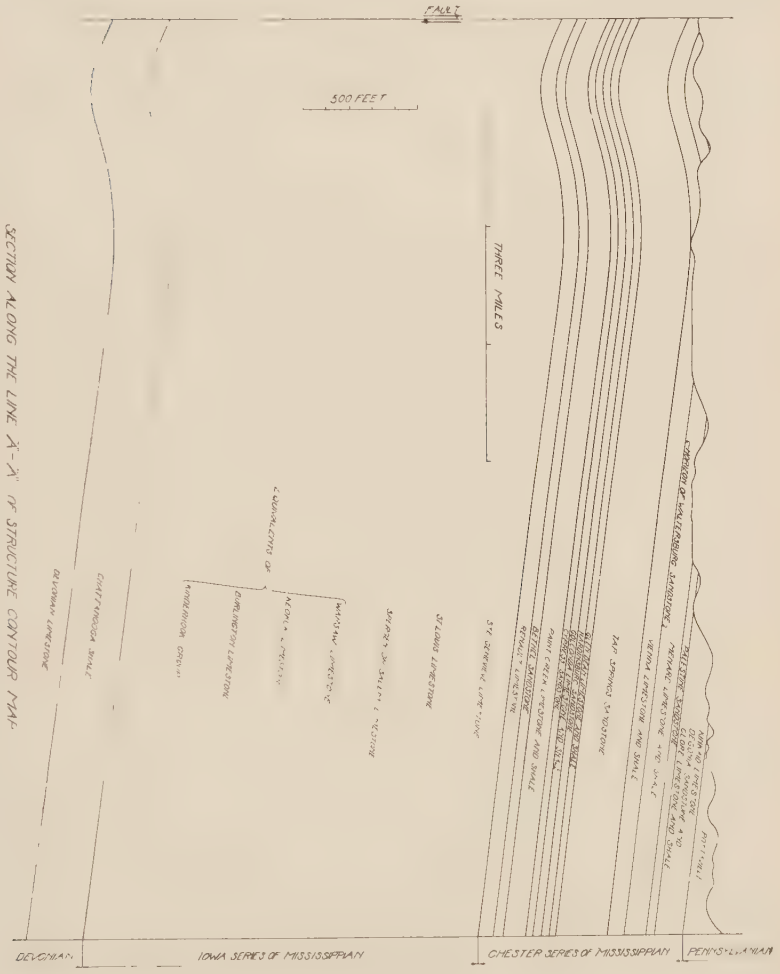
The greater portion of the area mapped is very complexly faulted and the conditions are such that the probability of any oil accumulation is very remote. West of Farmersville, however, six and one-half miles north of Princeton, there is an unfaulted area in which a distinct structural dome is present, which may be considered as a possible source of oil or gas production. It is not possible to predict the result of drilling in this dome because it is so far removed from any productive area, but if any wild cat development should be contemplated in the region, it would be wisest to place the wells at points where the structural conditions are the most favorable.

STRATIGRAPHY.

The rocks exposed at the surface about Farmersville are all members of the Chester Series of Upper Mississippian age. The lowest formation actually exposed at the surface within the area of the Farmersville dome is the Vienna limestone and shale. This formation is characterized by shale beds in its upper portion, which constitute one-half or more of the entire formation. The lower portion consists of limestone and shale layers interbedded. The limestone is particularly characterized by the large amount of flint or chert which it contains, commonly in the form of bands from one to three inches in thickness, lying essentially horizontal, parallel with the bedding. Where this cherty limestone has been subjected to long weathering the calcareous portion of the bed has been removed by solution, and the chert or flint remains with the residual clay. Flinty, residual beds of this sort are well exhibited about Farmersville, along the public highways north and west of the village.

At Farmersville a thin sandstone overlying the Vienna is exposed at an elevation between 480 and 500 feet above sea-level. This is the Waltersburg sandstone of the section, and probably does not exceed twenty feet in thickness anywhere in the area, and in places it is ten feet or less thick. This formation is exposed at a number of points along the public highways which radiate from Farmersville, and the difference in elevation of the outcrops of the sandstone serve to outline the dome structure centering a little west of Farmersville.

Overlying the Waltersburg sandstone, and well exposed about the dome and in many of the hills within the area where the Waltersburg and Vienna are present in the valleys, is the Menard limestone. This formation attains a thickness of 140 feet. In its lower portion it contains much calcareous shale with thinly bedded limestones, and some more compact limestone beds. The higher portion of the formation contains much more limestone, much of which is compact in texture, hard and brittle, breaking with a splintery fracture. The limestone beds of the formation are from one to two or more feet in thickness, being separated by shales which may be only shaly partings, or may be shale beds up to several feet thick.



Diagrammatic Section Showing Structure of the Farmersville Dome

The highest formation exposed within the dome area is the Palestine sandstone. This is a more or less massive, yellowish-brown to pink sandstone, of rather fine texture, which attains a maximum thickness of about 60 feet. In places it includes some sandy shale beds, but the more massive layers are most often well exposed. The sandstone is present capping the hills which lie around the borders of the dome, becoming a more continuous formation farther east, the dip of the beds finally carrying it beneath the higher formations of the Chester Series, and these in turn pass beneath the Pottsville beds of the Pennsylvanian.

POSSIBLE OIL AND GAS "SANDS."

The unexposed formations of Chester age within the limits of the dome, lying beneath the Vienna limestone, are (1) the Tar Springs sandstone, an alternating series of more or less massive sandstones and sandy shales, 200 feet or more in thickness, (2) the Glen Dean limestone, mostly shales, with a massive limestone bed ten feet thick at its base, the whole thickness of the formation being about 40 feet, (3) the Hardinsburg sandstone, for the most part a sandy shale with thin sandstone layers, the whole being about 30 feet thick. (4) The Golconda limestone, mostly calcareous shales with thin limestone layers, about 40 feet thick. (5) The Cypress sandstone, a thinly bedded sandstone formation about 30 feet thick. (6) The Paint Creek formation, an alternating series of hard limestone beds, some of which are oolitic, with shale partings, some of which may be several feet in thickness, the whole formation being about 100 feet. (7) The Bethel sandstone, a massive, fine-grained, yellowish-brown sandstone about 40 feet thick. (8) The Renault limestone, consisting of layers of hard blue to gray limestones with shale partings, the whole being about 80 feet thick. Beneath the Renault formation there is a great series of Lower Mississippian limestones (10), including from above downward, the Ste. Genevieve, the St. Louis, and the equivalents of the Spergen or Salem, the Warsaw, the Keokuk, the Burlington limestones, and the Kinderhook Group. This series is as much as 1,700 feet thick in the recently drilled well at Cedar Hill. There is likely to be a thin sandstone member from five to fifteen feet thick somewhere within 50 feet of the top. The lower

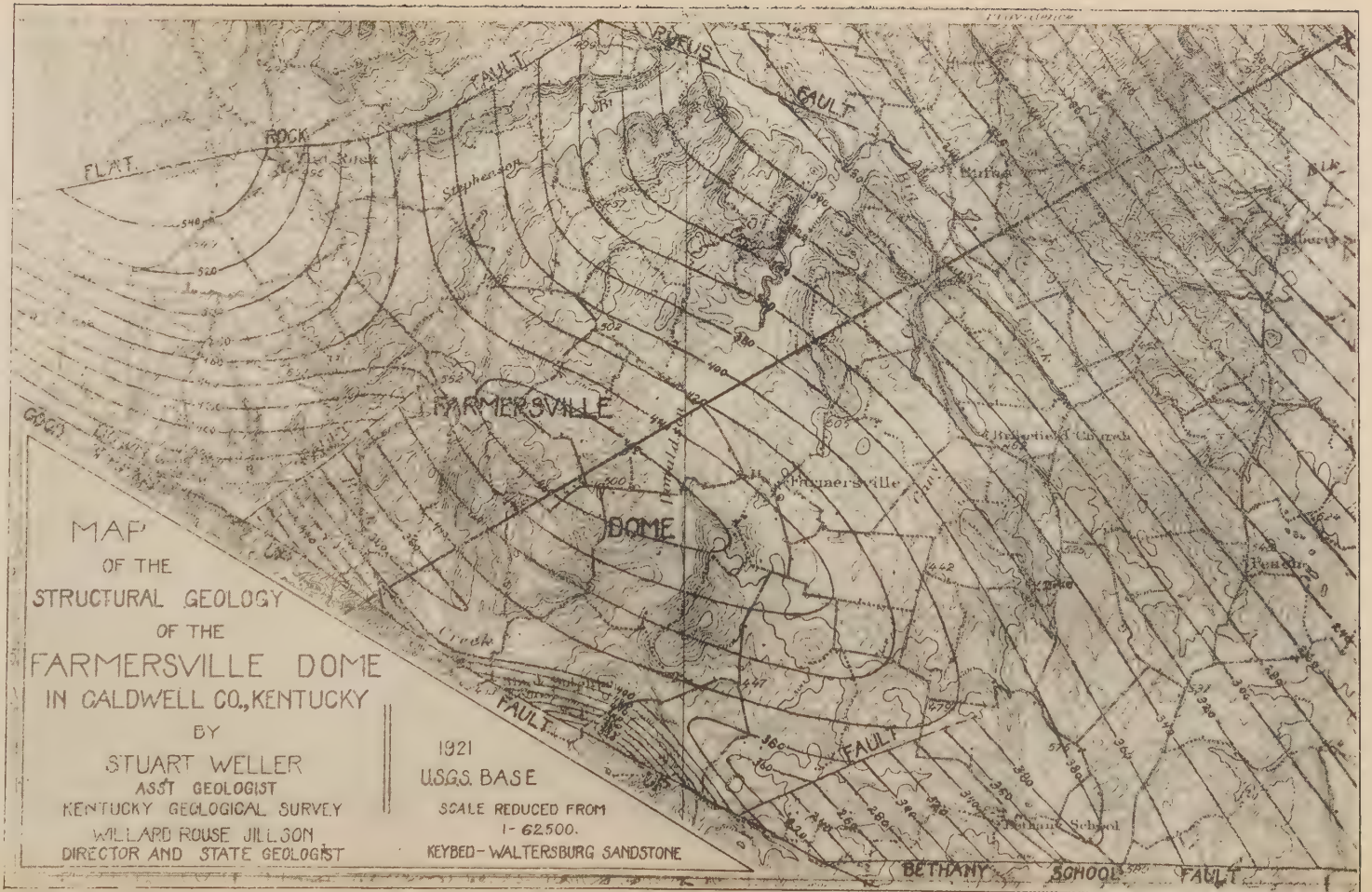
500 feet of this series of beds may be expected to be nearly black, hard, silico-calcareous shales, or an impure siliceous limestone, as in the Cedar Hill well. Beneath these Lower Mississippian limestones is the Chattanooga shale (11), a black, more or less fissile shale, 242 feet thick at Cedar Hill. Underlying the Chattanooga shale is a light colored, highly crystalline limestone (12), in the Cedar Hill well. This limestone is doubtless of Middle Devonian age.

STRUCTURE AND DRILLING LOCATIONS.

In the accompanying structure map it will be observed that the dome lies between faults to the north, south, and west, but no dislocation has been detected to the east and northeast, from which direction the oil, if present, would presumably have been accumulated. In order to test the structure a desirable location in approximately the center of the dome, is in the valley of a tributary of Donaldson Creek from the west, about one and one-fourth miles west of Farmersville. Other tests might be made upon the northeastern flank of the structure, in a general easterly direction through Farmersville to the valley of Caney Creek in the vicinity of Briarfield Church.

In this connection it should be stated that an igneous dike has been recognized at a point 1.1 miles southeast of Briarfield Church, and 1.9 miles southeast of Farmersville, the location of this dike being indicated by x on the map. The direction and extent of the dike is not known, but it would probably be unwise to prosecute the search for oil in the immediate vicinity of the dike.

The accompanying diagramatic cross-section of the Farmersville dome gives a clear idea of the strata which would be penetrated in drilling. The thicknesses of the several strata shown for the Chester Series are those which have been observed in surface outcrops within the Princeton Quadrangle, those for the beds beneath the Chester Series are taken from the data afforded by the recently drilled well at Cedar Hill. The section at the center of the dome would be as follows:


MAP
OF THE
STRUCTURAL GEOLOGY
OF THE
FARMERSVILLE DOME
IN CALDWELL CO., KENTUCKY
BY
STUART WELLER
ASS'T GEOLOGIST
KENTUCKY GEOLOGICAL SURVEY
WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST
1921
U.S.G.S. BASE
SCALE REDUCED FROM
1- 62500.
KEYBED- WALTERSBURG SANDSTONE
FLAT ROCK FAULT
RUFUS FAULT
FARMERSVILLE
DOME
Farmersville
Creek
FAULT
BETHANY SCHOOL FAULT

Chester Series.

MISSISSIPPIAN SYSTEM.

	Thickness	Depth
	feet	feet
Tar Springs formation, sandstone and sandy shales	200	200
Glen Park formation, shales and limestones	40	240
Hardinsburg formation, sandstone and sandy shales	30	270
Golconda formation, shales and limestone	40	310
Cypress sandstone	30	340
Paint Creek limestone and shale	100	440
Bethel sandstone	40	480
Renault limestone	80	560
Iowa Series (Lower Mississippian)		
Ste. Genevieve limestone	300	860
St. Louis limestone	350	1,210
Equivalents of Spergen, Warsaw, Keokuk, Burlington and Kinderkook formations	1,050	2,260
DEVONIAN SYSTEM.		
Chattanooga black shale	240	2,500
Middle Devonian limestone	?	?

SUMMARY OF DRILLING.

The possible oil and gas horizons in the Farmersville dome are the Cypress and Bethel sandstones at depths of 310 and 440 feet respectively, at the center of the dome. If nothing should be found in these sands drilling would probably have to be continued through to the top of Chattanooga black shale to reach the shallow "sands" of Warren County. The Middle Devonian limestones, from which the greater part of the oil production in southern Kentucky is obtained will be found just below the black shale. Still deeper production might be sought in strata of Silurian and Ordovician age, but the area is so far removed from localities where surface outcrops of these formations are exposed, that any prediction of their depth would be extremely hazardous. The estimated thicknesses of the formations given in the foregoing table are of course subject to some error, and it is possible that the distance to the base of the Chattanooga shale may be more or less than is suggested, with a possible error of 100 to 200 feet.

CEDAR HILL WELL.

A stratigraphic interpretation of the 2,000 foot dry hole at Cedar Hill is important in connection with any further oil and gas prospecting of this or the Farmersville region. Drill cutting samples from the Cedar Hill well have been generously furnished to the writer by Mr. F. K. Wylie of Princeton for laboratory examination and identification. Surficial examinations made in the field establish the fact that this well starts in the Ste. Genevieve limestone, about 70 feet below the contact between this formation and the overlying Renault limestone which is exhibited in the Cedar Hill quarry, one-half mile northeast of the well. The contact is at an elevation of 550 feet above sea level, and the top of the well is approximately 490 feet. The difference between these two elevations is 60 feet, but the slight dip of the strata to the northeast would somewhat increase the interval at the well, to approximately 70 feet. The Chattanooga shale was penetrated at a depth of 1,630 feet. This depth, added to the 70 feet of Ste. Genevieve limestone not represented in the well section gives a total thickness of 1,700 feet for the Lower Mississippian or Iowa Series.

The nearest Lower Mississippian section which has been studied carefully is that of Hardin County, Illinois ([1]), where a total thickness of the equivalent beds is estimated to be 1,450 feet. At no locality in Hardin County, however, is the complete section exposed, and the thickness of some of the members has been estimated from scattered surface outcrops, and some of the estimates may be too low. In the Hardin County section the beds are divided as follows:

Ste. Genevieve limestone	300 feet
St. Louis limestone	350 feet
Warsaw (including Spergen) limestone	250 feet
Osage limestones	550 feet

No lines of sharp demarkation have been recognized in the Hardin County section, between any of the formations, and they doubtless represent a continuous, uninterrupted sequence of sediments.

The cuttings from the Cedar Hill well which have been available for study are not complete, the first sample being from a depth of 250-255 feet. From the depth of 310 feet to the bot-

[1]Ill. State Geol. Surv., Bull. No. 41, pp. 91-120 (1921).

tom of the well a continuous series of cuttings has been saved, although a sample was not taken from each screw, but in general only when the driller recognized some change in the rock, there being 56 samples in all. There is no sample from limestone of Ste. Genevieve age, at least there are no cuttings showing any oolitic structure, which would be expected in the Ste. Genevieve. If a maximum thickness of 300 feet of this formation is present, as is indicated in Hardin County, Illinois, the bottom of the Ste. Genevieve in the well should be at a depth of 230 feet, and the first cuttings are at 250-255. These first cuttings are of a character that might well be expected in the St. Louis limestone, situated next beneath the Ste. Genevieve, and all of the cuttings studied, down to the depth of 550 feet are of similar character; gray limestone, varying somewhat from dark gray to nearly white, with much chert, some samples being much more cherty than others. If 550 feet is the bottom of the St. Louis limestone then the formation is 320 feet thick, assuming 300 feet for the Ste. Genevieve. This compares favorably with the Hardin County section where an estimated thickness of 350 feet of St. Louis limestone is present.

The sample from the depth of 550 to 555 is a black rock which seems to be a hard shale with much calcium carbonate and silica. This silico-calcareous shale passes downward into more calcareous beds, the prevailing character to 800 feet being brown limestone, somewhat gray in some samples, with varying amounts of chert and some pyrite, some of the limestone is siliceous in addition to the included chert. From 800 to 1,000 feet the strata are limestone, but the beds are grayer in color than those above 800. Most of the samples contain fragments of chert, and some of them have considerable quantities of pyrite. From 1,000 to 1,100 feet the samples are brown limestone with chert and pyrite like those above, with some silico-calcareous shales below.

From 1,100 to 1,600 feet the samples are all a dark, mostly nearly black, silico-calcareous shale without chert. From 1,600 to 1,630 feet the samples become somewhat different. From 1,602 to 1,610 the sample is darker and more siliceous than those higher up. From 1,610 to 1,615 the same sort of material is shown with some lighter gray limestone. From 1,615 to 1,625

the sample is greenish-black in color and is practically without lime. The Chattanooga shale begins at 1,630.

In this Lower Mississippian section the limits of the recognized formations of the Mississippi valley are not determinable. The most noticeable line is at 1,100 feet, where the change from beds which are clearly limestone to the dark, silico-calcareous shale occurs. This lower division, from 1,100 to 1,630 may represent the Osage, although it is very different in lithologic character from the Burlington and Keokuk limestones of the Mississippi valley. No fragments of fossils whatever have been observed in any of these cuttings. The thickness of these beds, 530 feet, is comparable with the 550 feet of the Osage section in Hardin County, Illinois, where the beds are represented on the surface almost wholly by residual cherts. It is possible that originally the Hardin County sediments may have resembled the beds present in the Cedar Hill well.

The interval between the top of the presumably Osage sediments and the possible base of the St. Louis limestone, between the depths of 550 and 1,100, a total thickness of 550 feet, is more than twice the estimated thickness of the combined Warsaw and Spergen in Hardin County. Some portion of the upper part of this series of beds should perhaps be added to the St. Louis limestone, and some of the lower portion may belong in the Osage, but it doubtless does include the equivalents of the Warsaw and Spergen farther north.

The Chattanooga shale in the Cedar Hill well is 242 feet in thickness, which is considerably greater than has been observed in well logs in the producing oil fields of southern Kentucky, where it is 40 to 50 feet in Allen County, but in Hardin County, Illinois, there is an estimated thickness of 400 feet of the formation exposed in the Hicks dome. The lithologic character of this shale, as shown in the cuttings, is like that of the Chattanooga elsewhere. It is brown to black in color, and some of the fragments show the characteristic *Sporangites*. Some layers of the shale contain much pyrite, one sample from the depth of 1,835 feet being particularly full of pyrite fragments.

Beneath the Chattanooga shale, beginning at a depth of 1,872 feet, there is a very white, highly crystalline limestone. No fossils have been contained in any of the cuttings, but it is pre-

sumably a limestone of Middle Devonian age. The last sample examined at 1,882 feet is from this limestone, but it is known that the well has been drilled to a depth of 2,000 feet.

Description of Cedar Hill Well Log.

	Thickness	Depth
Iowa Series (Lower Mississippian)		
No samples	250	250
Gray limestone, more or less crystalline, with chert	5	255
No samples	55	310
Dark and light gray limestone, more or less crystalline, with chert	240	550
Black, silico-calcareous shale	10	560
Dark silico-calcareous shale with some gray limestone	25	585
Brown limestone with chert and pyrite	65	650
Brown to gray limestone with chert and pyrite	30	680
Gray and brown limestone with chert and pyrite	350	1,030
Brown limestone with some silico-calcareous shale, some chert and pyrite	70	1,100
Dark to black silico-calcareous shale with some pyrite but no chert	502	1,602
Black, silico-calcareous shale, more silicious than that above	8	1,610
Black silico-calcareous shale with some gray limestone	5	1,615
Greenish-black, highly silicious shale	10	1,625
No sample	5	1,630
Chattanooga Shale (Devonian).		
Brown to black shale with Sporangites	135	1,765
Black shale with conspicuous pyrite bed at 1835	107	1,872
Middle Devonian Limestone		
White crystalline limestone	10	1,882
Total depth		1,882

IX

DRAINAGE PROBLEMS IN KENTUCKY.

By Willard Rouse Jillson.
Director and State Geologist.

INTRODUCTION.

Due to its geographic position and topography, Kentucky, like many other states of the Mississippi Valley, finds its general health and agricultural interests closely identified with the proper solution of a group of well defined drainage problems. While for the greater portion of Kentucky natural drainage effected by the normal erosin of the streams is ample and sufficient, certain restricted areas, due to their peculiar topography, must necessarily employ artificial drainage to carry off excessive overflow waters, or reclaim swamp lands. Drainage is herein defined as an artificial scheme of ditching designed to remove excessive water from relatively large areas, either through systems of open channels or by covered conduit or tile, for the purpose of improving agricultural land, or advancing the general sanitary and health conditions.

NEED OF DRAINAGE.

Although the question of drainage is more forcefully realized by the people of western Kentucky in the Ohio bottoms, the Western Coal Field and the Purchase region, because of the large areas of lowlands in these sections, it is a question of real importance to the people of the entire State, since it means not only the reclamation of swamp lands and the control of floods on overflow lands, but also the improvement of the general health and the increase of the total capitalization of the State. There are approximately 570,000 acres of swamp and overflow land in western Kentucky alone, practically all of which is susceptible to reclamation and increased productivity if properly

DRAINED AND UNDRAINED LANDS.
These flat lands are located just North of South Park Station on Wilson's Creek, Jefferson County, Ky. The lands under cultivation on the left have ditches and tile drainage. The brush-covered area on the right capable of the same results is undrained.

drained. In many instances no engineering difficulty stands in the way of draining any particular region. When we consider that these swamp and overflow lands, now partially improved it is true, but for the most part abandoned and unproductive, cover an area of about the same size as Luxemburg (Europe), which had a population of 259,899 in 1910,[1] it will be seen that this State has a real opportunity in developing these areas and allowing for normal and prosperous increase of its population.

While it is not to be inferred that the same amount of people could be crowded onto improved lands in Kentucky as may occupy through force of necessity the same area in good agricultural lands in older portions of the world, it is nevertheless a fact that these areas which now serve little or no agricultural purpose and act at the same time as a great deterrent to the public health, could be made attractive to the intelligent farmer as healthful homestead sites. Practically all of these areas are crossed by the great railroad systems of Kentucky, which would allow a larger and more intensified cultivation of these lands

[1]New International Encyclopedia, Vol. XVI, p. 497.

A FORMER SWAMP CULTIVATED.

This portion of the J. H. Caperton ranch now drained by the South ditch was formerly under water for long periods. It now supports pasture, hay and grain fields.

than might in other cases be anticipated. In actual elevation many of the overflow and boggy lands of Kentucky are naturally sufficiently elevated above the neighboring water courses to make drainage feasible, but this is usually beyond the reach of the individual, and must be taken up through county or state organizations, employing whenever feasible, Federal aid.

Sanitary drainage is a matter which affects in some way or other, either directly or indirectly, the health and physical well being of every citizen. There are few communities where the conditions of the general health could not be improved by careful attention to proper drainage of the vicinity. This should include not only the proper disposal of municipal sewage, but the removal of all standing water in close proximity to the town or village. Sanitary drainage is feasible in many ways, but probably is most marked in its effective prevention or the

THE NORTH DITCH.
The view is Eastward from the Third Street Bridge. The filling up of the channel with willows and other small vegetation is evident.

diminution of diseases of the malarial type. The removal of standing water eliminates at the same time the greatest obstacle to good farming in many regions, and with it the breeding places of mosquitoes, which insects are now well recognized as the only carriers of the malarial germ. Where there are no swamps or boggy localities, the mosquito nuisance is not felt, and

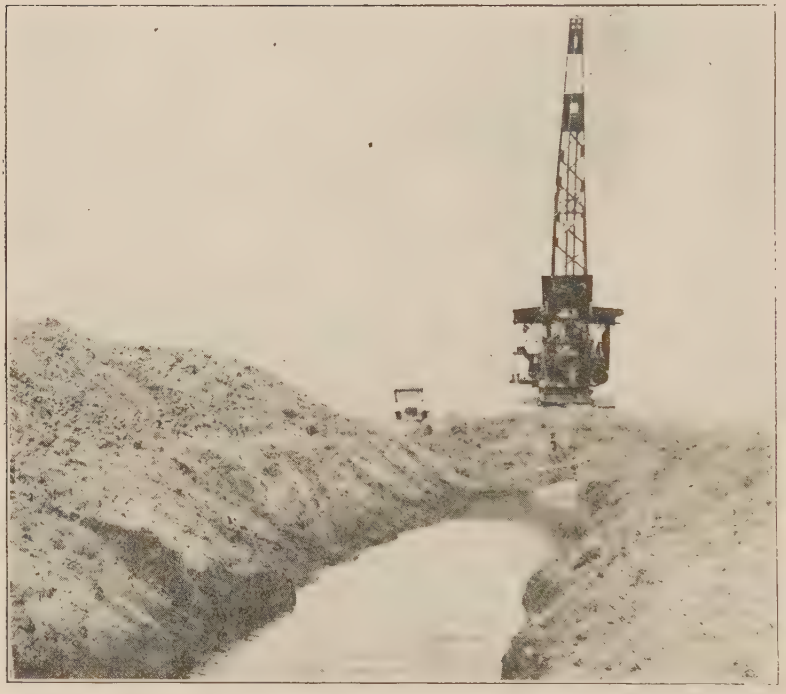
as a consequence malarial influences are obviated. It is a fact that in many parts of eastern Kentucky where the system of natural dendritic drainage is almost perfect, the mosquito is rare and malaria practically unknown.

HISTORICAL.

The subject of agricultural drainage is probably quite as old as the art of farming. Rich overflow lands as well as swamp lands have long claimed the attention of agricultural peoples, and this is particularly true of the valleys of the Nile and Jordan, where even in times of great antiquity large areas were watered artificially and drained artificially in order to allow the use of these rich though naturally unproductive areas. Artificial drainage was practiced by the Greeks at a very early time when the marshy swamp lands about the Lake of Copias near Thebes, embracing about sixty thousand acres, were reclaimed.[1] On the North American continent the Aztec kings, probably about the 14th century, built their city on the island in the lake in the Valley of Mexico, and protected it by dykes of great magnitude. In Europe, Holland has been engaged in the construction of vast drainage works for many centuries, and large areas have been reclaimed from the sea through the construction of great dykes. In this instance gravity drainage is impossible over large areas. The water in these drainage canals is discharged by pumping, the power required being generated through the use of many large wind mills. These wonderful Dutch projects, known throughout the world, have added thousands and thousands of acres of rich and productive agricultural lands to Holland.

Much work has been done within the last few decades in the United States by individuals, corporations, counties and states. Chief among the important projects are those of New Orleans, La.; Florida, Minnesota, North Dakota, and in the lowlands of Indiana and California, and other States. In Kentucky, drainage enterprises have been under way for over thirty years, the first project having been started about 1890. The growth of drainage projects in this State is well illustrated by the following table, which shows an increase from slightly more than fif-

(1) Proceedings of Drainage Convention North Carolina Geological and Economic Paper No. 17, p. 45.



DITCH DIGGING IN A SWAMP.

This excavator-crane is operating under the normal conditions of high water table in soft swamp lands. These machines are used by the Dept. of Dykes, Vancouver, B. C.

teen thousand acres in the last decade of the 19th century to 112,000 acres in the last half of the last decade, i. e., from 1915 to 1921.

1.

Kentucky Drainage Projects.[1]

Date of organization of drainage enterprise	Land		Assessed Area	
	Acreage	Per cent of total	Acreage	Per cent of total
All operating enterprises ...	358,480	100.0	358,480	100.0
1890 to 1899 (1)	15,111	4.2	15,111	4.2
1900 to 1904	28,085	7.8	28,085	7.8
1905 to 1909	69,741	19.5	69,741	19.5
1910 to 1914	131,160	36.6	131,160	36.6
1915 to 1919	112,583	31.4	112,583	31.4

(1) Includes 800 acres under individual ownership on which drainage was begun in 1888.

STATE DRAINAGE AREAS.

Those sections of Kentucky in which artificial drainage is destined eventually to bring about changed and improved conditions in health and agriculture do not occur as essentially contiguous regions. They may be divided, however, into three classes. These classes are as follows:

(1) Overflow lands. These are the low bottom-lands of the State which are subject to seasonal overflow, where such overflow is not normally drained off from the land directly following the ebbing of the flood waters. Good examples of this type of land are found in close proximity to the Ohio River in the Ohio River bottoms from Catlettsburg to Hickman.

(2) Valley filled lands. These lands are found principally in the western coal field where sediments washed in from the erosion of the hills instead of being removed by the streams have become impounded and have filled up the valley. An excellent example of this type of typography is found in Webster County in the vicinity of Clay.

(3) Swamp lands. The swamp land areas of Kentucky are relatively small. These occur bordering the tributaries

[1]U. S. Census, 1920.

MAP OF THE SOUTH PARK REGION.

The contrast of valley filled lowlands and rounded upland knobs is well depicted in this part of Jefferson and Bullitt Counties, Ky.

of some of the streams, emptying into the Ohio and Mississippi Rivers, especially in the "Purchase" region.

PILE DRIVER AT WORK.

This is the same machine No. 208 shown elsewhere rigged as a steam shovel excavator. Its adaptability to other occasional uses such as pile driving give it increased value to the operator.

In all these types of drainage areas the sediments involved are loose and readily susceptible to the employment of drainage projects.

DRAINAGE ENTERPRISE LEGISLATION.

The majority of the drainage enterprises in Kentucky are in reality drainage districts under the control of the county drainage commissioner. In Jefferson County where considerable work has been carried on, the enterprises are known as county drains, and are under the fiscal court. Nine of the enterprises operating in the State at present are under individuel ownership, but the drainage law of 1912 provided that in each county where there is a public ditch, drain, levee, or similar improvements established, the county judge should appoint a board of three drainage commissioners. In 1918 an amendment to this law provides for the appointment of one county drainage commissioner. The drainage districts, with but a single exception, have been established by the county judges in accordance with the laws of July 10, 1893 (ch. 266), of March 23, 1900 (ch. 30), and of March 19, 1912 (ch. 132).

A "JACK AT ALL JOBS."

The excavating crane because of its long boom and extreme mobility under flooded conditions is adaptable to many uses. Here it is being used as a steam derrick hoist.

The law of 1893 was the first one to be passed in Kentucky with relation to drainage of the State. Under this law one or more persons interested might file a petition for a drain, and the count judge would subsequently appoint three viewers to examine the land that would be affected by the proposed work, locate the drain, assess benefits and damages, and determine whether the proposed improvement would be a public utility and benefit. The judge also ordered the establishment of the district finally, or dismissed proceedings, basing his judgment upon the report of the viewers. The law of 1912 required that only the original petition be signed by one or more owners of the land which would be assessed for the enterprise, but in 1918 (ch. 14), a law was made to require the signatures of at least 25% of the landowners, or the owners of not less than 25% of the land which might be affected. The drainage law of 1912 required that all ditches, levees, and other public improvements under control of the board of drainage commissioners, shall be kept in good repair by that board, which is authorized to appoint

a superintendent of drainage to have charge of the work. Assessments for maintenance and repair work may be made, apportioned like to cost of original construction, but not to exceed in any year 10 per cent of that cost.

The law of 1918 provides for maintenance of drainage work by the board of drainage commissioners. Both of these statutes define as public ditches all watercourses into which any public drains empty, and place such streams under control of the county drainage commissioners. The law of 1918 does not limit such natural public drains to non-navigable streams, as was done in the earlier statute. Further details concerning the drainage law of Kentucky may be found by consulting the statutes.

THE SOUTH DITCH.
The view is West from the Third Street Bridge. Willows and other small shrubbery have covered the bottom which will retard the flow and hasten the bottom filling.

EXTENT OF DRAINAGE.

The total amount of drainage completed by the various enterprises in Kentucky to and including the year 1919 comprise 664.5 miles of open ditches, and 86.2 miles of tile drains, and

0.2 mile of accessory levees. The additional lengths under construction totaled 77.0 miles of open ditches and 1.0 mile of tile drains. These figures, however, do not include levees or drains installed for individual owners of farms, which may be regarded as additional to the main enterprises, nor do they include the works of flood protection of levee districts that had not undertaken the construction of ditches or tile drains. No pumping districts for land drainage are found in Kentucky: The extent and amount of capital invested in drainage enterprises in Kentucky is given in the following tables:

II.

Land and Capital Invested in Operating Enterprises,—1920.*

Kind of Works	Land		Capital		
			To Dec. 31, 1919		Additional required to complete.
	Acreage	Per cent of total	Amount	Per cent of total	
All kinds	358,480	100.0	$1,521,725	100.0	$299,271
Open ditches only ...	345,605	96.4	1,406,696	92.4	295,701
Open ditches and levees	1,140	0.3	8,333	0.5	.....
Tile drains only	117	(1)	1,979	0.1	.....
Open ditches and tile drains	11,618	3.2	104,717	6.9	3,570

(1) Less than one-tenth of 1 per cent.

*U. S. Census, 1920.

A SEWER DIGGER.

This sort of machine can be used satisfactorily by municipalities in sanitary work. It will successfully excavate a ditch four feet wide and 20 feet to 30 feet in depth.

III.

Land in Operating Enterprises, Classified by Average Depth of Branch Ditches: 1920.*

Depth of Branch Ditches	Acreage	Per cent of Total
All operating enterprises	358,480	100.0
Less than 3 feet	4,491	1.3
3.0 to 3.9 feet	21,031	5.9
4.0 to 4.9 feet	41,243	11.5
5.0 to 5.9 feet	19,379	5.4
6.0 to 6.9 feet	21,444	6.0
7.0 to 7.9 feet	15,747	4.4
8.0 to 8.9 feet	13,579	3.8
Not reporting branches	221,566	61.8

*U. S. Census, 1920.

KENTUCKY AND THE SOUTHEASTERN STATES.

Drainage work of a modern character in the southeastern States began with the enactment of the North Carolina Drainage Law in the year 1909. Up to that time none of the southern States had what would now be considered a workable drainage law. Hence little progress had been made. Among the difficulties which confronted the pioneer drainage engineers of the southeastern States were the following:

(1) The validity of the laws had not been established.
(2) Many laws were difficult to operate under.
(3) Many engineering and construction problems had not been solved.
(4) No market had been created for the bonds with which the districts were to be financed.
(5) Landowners were frequently unfamiliar with the benefits of drainage.
(6) Ignorance of the nature of the projects frequently resulted in widespread opposition of the drainage projects.

At the time drainage work started in 1909 there were approximately forty-six and one-half million acres of swamp, wet and over-flowed land that needed drainage. These lands were divided among the States as follows:

IV.

Area of Swamp, Wet and Overflow Land, 1909, *Southeastern States*

State	Area in Acres. Total	Permanent Swamp	Periodically Swampy	Periodically Overflowed
Alabama	2,604,000	267,000	512,000	1,825,000
Florida	19,689,000	7,713,000	10,279,000	1,877,000
Georgia	7,896,000	2,271,000	2,582,000	3,043,000
Kentucky	1,715,000	15,000	200,000	1,500,000
Mississippi	6,008,000	560,000	2,570,000	2,878,000
North Carolina	5,653,000	2,220,000	2,488,000	945,000
South Carolina	4,440,000	2,023,000	1,906,000	511,000
Tennessee	1,270,000	40,000	16,000	1,214,000
Virginia	1,116,000	440,000	125,000	551,000
	50,571,000	15,549,000	20,678,000	14,344,000

The amount of drainage which had been completed by 1920 is indicated in the following table:

DRAINED LAND-CAPERTON RANCH.

This ranch of 1,300 acres straddles the South ditch between Louisville and South Park. It is practically all tillable land. Knob topography shows in the background.

V.

Areas Completely Drained, 1920, Southeastern States.

State	Amount of Swamp, Wet and Overflowed Land 1909 Acres	Amount in Drainage District 1920 Acres	Cost of Drainage Improvements. (District)	Area still Unorganized Acres
Alabama	2,604,000	.....	.....	2,604,000
Florida	19,869,000	1,367,000	$11,529,958	18,502,000
Georgia	7,896,000	104,000	828,683	7,792,000
Kentucky	1,715,000	475,000	1,650,925	1,240,000
Mississippi	6,008,000	1,910,000	7,239,607	4,098,000
North Carolina ..	5,653,000	543,000	3,623,518	5,110,000
South Carolina .	4,440,000	155,000	618,083	4,285,000
Tennessee	1,270,000	443,000	3,041,515	827,000
Virginia	1,116,000	.....	.....	1,116,000
Totals	50,571,000	4,997,000	$28,532,289	45,574,000

At the present time about 10% of the wet, overflowed and swamp lands in the southeastern States has been included in drainage enterprises. It should be stated, however, that on much of this land work has never been started, while some main tracts have been provided with the major outlet drains only. Much of the work which has been done has been contracted along two major lines. A considerable portion of it at least will have to be deepened and extended at an additional expenditure of a considerable amount. In addition to 45,574,000 acres of overflowed land in the southeastern area, there is an area of land at least twice as great, that is badly in need of tile drainage. During the last decade there has been a steady increase in the amount of tile used in the southeastern States.

FLOOD CONTROL IN KENTUCKY.

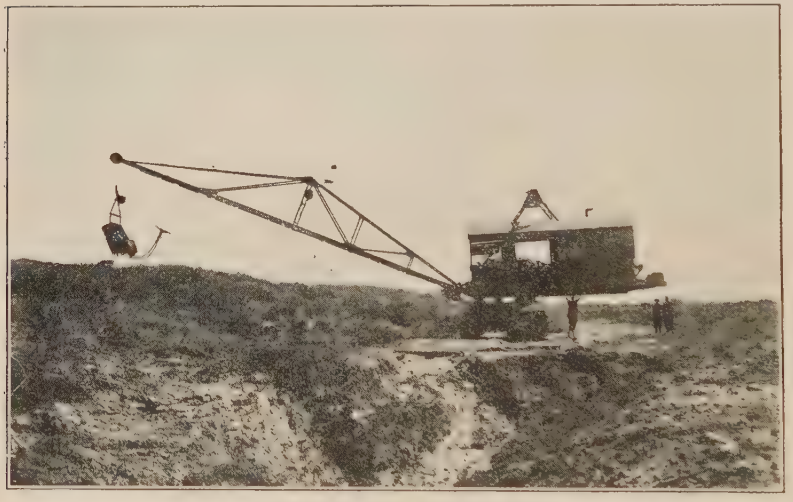
The subject of flood control is one which invites serious consideration, and widespread interest, throughout the State of Kentucky. The engineering problems involved in this work have by no means been solved, and no means have yet been devised to protect the forests which are rapidly disappearing from the headwaters of the major streams of this State. Without some definite plan to be followed in the near future, the situation resulting from periodic floods is one which may be

CLEANING OUT AN OLD DITCH.
The excavator-crane may be used to advantage in deepening silt-filled ditches and in clearing small vegetation from the sides.

expected to become gradually worse, rather than better, due to the extension of the area of cultivated lands and the removal of the forests cover. Both of which conditions allow a rapid run-off of the heavy seasonal rains. In Kentucky all of the major streams record a sudden rise after heavy rains, and then quickly return to the normal. They are what is called "flashy," having generally a high rate of discharge for a short period of time. To prevent erosion the ditches draining to them must be adequate to take the ordinarily sudden flow which comes after heavy rains or thaws. The intensity of the rainfall over short periods of time, therefore, becomes of great importance. Since the intensity of precipitation varies in different parts of the State, drainage projects will have to be adjusted accordingly.

The ideal in flood control would seem to be not only the enlarging of drainage ditches to take the occasional floods, but to so control run-off in the various areas as to deliver a fairly constant flow, or at least some flow which would not pass a certain predetermined amount. The prevention of floods differs con-

siderably from the control of floods, and the drainage engineer, due to the public neglect of the factors which would prevent floods, is concerned therefore primarily with the control of floods. The problem is to so regulate the discharge of flood water of any stream that it will rise only to a predetermined amount above its normal level. For this purpose it is necessary to study the character of the various drainage basins, and their normal drainage, and that of their tributary streams. It is necessary to know their rate of flow in flood, the time interval which the flood crest generally takes to reach the main stream, and the effect of the crestal floods discharged by the various tributaries on the flood crest of the main streams.



A MODERN DITCH-DIGGER.

This is a caterpillar self propelling steam shovel and boom. It is the No. 208 machine of the Pawling and Harmschfeger Co., now being used by the U. S. Reclamation Service in a number of its projects and could be used to advantage on many Kentucky drainage projects.

In reviewing the history of flood control it has been found that the most destructive floods occur when the crest flood of the main stream is met by the crest flood of the major tributaries. This will not last except for a very short time, but is frequently sufficient to be very disastrous to both life and property. By straightening and widening the channels of the main stream the delivery of flood waters may be hastened, and the

flood crest in the main stream is reduced in magnitude. Though this process generally insures some benefits, the total amount of water to be delivered by the stream is not greatly affected by it. When such measures as have been briefly suggested are ineffective or impossible to secure, the construction of retention flood reserve reservoirs becomes the necessary last resort. These reservoirs do not necessarily need to be large impounding basins with high dams. It is frequently possible on the tributaries of streams to erect a series of smaller dams and flood control basins which will operate to effectively retard the overflow of the water and prevent a simultaneous discharge of flood crests from the tributaries and main streams. This system of flood control engineering is well illustrated in the Miami Conservancy District near Dayton, Ohio, which is essentially a series of retarding flood basins at selected points on both the tributaries and the main streams.

PREVENTION OF EROSION.

The prevention of erosion of the cultivated soils of Kentucky has been a subject of much oral and printed discussion.

GRAVELS NEAR SEDALIA.

Practically all of the gravel deposits of the Purchase Region are found to be badly washed wherever the forest or meadow cover has been removed. This exposure in Graves County is characteristic.

It is computed that an equivalent of $1,300,000.00 annually goes down the streams of this State and is irretrievably lost in the rapid erosion of hillside farm lands and scouring out of fertile bottom-lands. Erosion is very active on the hill soils of Kentucky, especially in the Mountain and Knob regions where the soil is usually thin. In these regions the soils are generally of a shallow sandy loam, clayey-loam or a sandy-clay nature, underlaid generally at a depth of from a few inches to a foot or so by impervious sands or sandstones which do not afford a good absorbing agent for rapid precipitation. These soils are also low in humic acid because of their fine grained texture, and are very susceptible to rapid erosion or wash.

RAPID EROSION CHECKED.

This badly washed hillside is located in Pendleton County, Kentucky. Sweet clover has been planted in the gullies to check the rapid wash of the soil. See illustrated in the next photograph the results obtained.

It is estimated that the rivers of the United States carry over 100,000,000 tons of material each year, which has been robbed, for the most part, from the best and most productive farming areas. The James River of Virginia, with a 10-foot flood crest, has recently been figured to have carried 300,000 cubic yards of soil away during twenty-four hours, and the rivers of North Carolina carry away some 4,000,000 tons of soil, resulting in a yearly loss of over $2,000,000 to that State. It is figured that

the rivers of Kentucky carry to the Mississippi River annually 5,000,000 tons of soil, which could it be retained within the State would add materially to the prosperity of this region.

Prevention of erosion is an engineering proposition, though one which is not very complicated for minor drainage units. While the farmer is competent to carry on much of this work, he should only do so following the advice of some competent engineer. Erosin is principally due to the uncontrolled movement of water over an unprotected surface, coupled with the inability of the soil to properly absorb this water. Anything which may be done to block this rapid movement and promote absorption of the water will lessen erosion and stop it before it begins, which is really the ideal. There are many ways of

WHAT SWEET CLOVER DID.

The practical results which may be obtained by using a good cover crop like deep rooted clover to check rapid wash is well illustrated here. This is the same field as shown in the photograph above, but later in the season. Rapid erosion has been stopped and this field saved.

promoting rain absorption by the soils. Among these may be stated the growing of cover crops, turning under vegetation and humus, and the practice of better methods of cultivation.

While all of these will help, they cannot in themselves entirely prevent erosion in climates of heavy precipitation. In the South generally, with the exception of Kentucky and Virginia, the use of terraces judiciously and correctly designed,

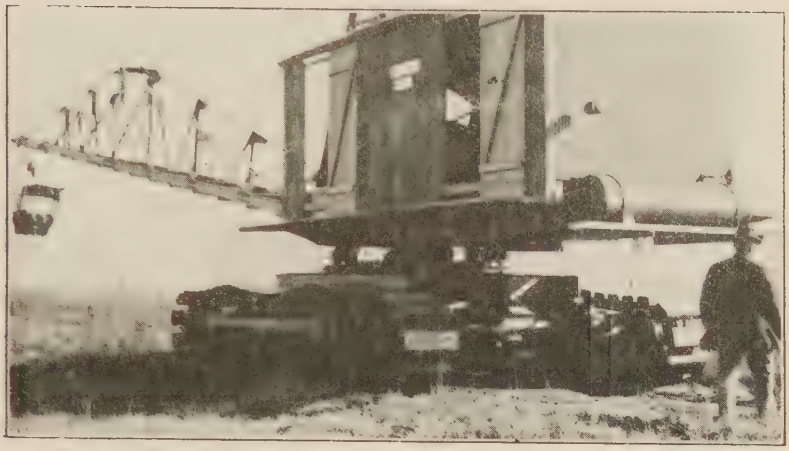
has been found to meet very satisfactorily local conditions. They are entirely practical and can be used upon washed lands on any farm, and are within the means of the small farm operator. With the introduction of terraces in some Kentucky localities, coupled with the suggested methods of cultivation and cropping, the extensive and bankrupting washing and erosion now found in many parts of this State might be practically eliminated.

VALUE OF RECLAIMED LANDS.

It is quite impossible to draw generally applicable conclusions for the value of drainage improvement, because of the extreme range of cost and the varying value of results obtained. The improvement of one section may cost from $10.00 to $20.00 per acre, another may cost much more. This drainage improvement might increase the value of land from an original value of from $10.00 to $15.00 per acre to $100.00 or $200.00 per acre. This has frequently been the case in the drainage projects of North Carolina and Virginia. Recently, North Carolina* has announced that a half million acres in its Coastal Plains Region has been increased in value by drainage from 25 to 50 cents an acre to from $50.00 to $200.00 per acre. In the State of Minnesota, through the completion of some rather large and recent enterprises there, the land was raised from $1.00 an acre to $300.00. In the State of Kentucky the completion of drainage projects in Jefferson County and in Clay County, which are representative of the areas principally in need of work in this State, has resulted in the increased valuation of the land from $5.00 to $100.00 and $150.00 per acre.

Other individual cases in Kentucky could be cited where the improvement has resulted in a much greater increase of value to the agricultural districts. It is a fact that there are still large areas of poorly drained and overflow bottom lands in the western and southwestern part of this State which if properly drained could be reclaimed from a valuation of not more than $2.00 to $5.00 per acre to a valuation of $50.00 or $100.00. At the present time there are within the State of Kentucky 270,626

*North Carolina adds $60,000,000 by Reclamation, J. H. Pratt, Natl. Reclamation Magazine, Vol. 1, No. 1, p. 6, Dec., 1921.



AN EXCAVATING CRANE IN DETAIL.

The compact yet sturdy construction of these "ditch diggers" is well illustrated. The caterpillar tread gives them extreme mobility even in submerged or boggy places, thereby allowing the work to proceed even during flood periods.

farms. Of these, 5,817 report the drainage enterprises already established, and 19,592 farms report the pressing need of new drainage enterprises. There are 773 farms principally within the levee districts of the Mississippi and Ohio Rivers which could be improved by drainage projects.

SUMMARY.

While the benefits accruing from drainage enterprises in Kentucky, as in every other state, are largely materialistic, and while it is certain that no drainage enterprise here would ever be undertaken if the project did not offer the prospect of a large capital return, it may be said that in the race for wealth the real fundamental thought behind all drainage projects—that of providing new and better homes for self-supporting citizens – should not be forgotten. The duties of our day in reclamation work really go far beyond the making of money. Any district in Kentucky which is to be successfully improved by drainage, or reclaimed from swamp, must not only be a profitable investment, but must provide a larger habitable and more prosperous agricultural region capable of a greatly increased production and capital assessment.

RECLAIMED LAND IN JEFFERSON COUNTY.

These bottoms are drained by the North Ditch. The area is about three miles south of Louisville. Typical Knob topography is seen in the background.

Engineers and drainage commissioners should not regard the completion of their contract as an end of the work. The right kind of people, those who are suited to the land, should be drawn into the district. The newly reclaimed or improved areas should not be left to inexperienced managers, who frequently through ill advised methods require the settlement of the land two or three times over. This sort of thing is unnecessary, and too costly. A good settler is one who has a small capital, considerable experience in farming reclaimed or improved lands, and possessed of a family. He should not have too much land, as it will be apt to break him. A few thousand dollars of capital is absolutely necessary.

A KENTUCKY HILLSIDE OF NO VALUE.
When the Jefferson County farmer cut away his brush cover on this hill he threw his land away. Thousands of tons of soil have been removed here by erosion.

State laws should be devised to eradicate the swindling of unsuspecting investors. Land frauds must and will eventually be stopped. Closely following the opening up of each newly reclaimed or improved area, should come the establishment of a number of well selected families, with competent and sufficient

AN INEXCUSABLE BUT COMMON CONDITION.

The removal of the timber cover from steep hillsides invites this farming disaster which is a growing menace in many parts of Kentucky. The geologic formation here is The New Providence (Mississippian) and the location is South of Louisville in Jefferson County.

hired help. The hired man soon becomes a renter on this tract, and follows from this position to that of landowner in natural sequence. The financing of Kentucky's new drainage projects is one of the most important problems to be solved in the present decade. The large amount of drainage which is now needed in this State will not be undertaken and satisfactorily completed until such bond issues as are necessary for these projects are made as safe or safer than the best municipal bonds the market affords.

X

RECENT MINERAL PRODUCTION IN KENTUCKY

By Willard Rouse Jillson.
Director and State Geologist.

THE KENTUCKY GEOLOGICAL SURVEY.

The State of Kentucky is one of the richest mineral resource storehouses of the Appalachian region. Within its area of 40,598 square miles there are found in commercial and in smaller quantities in the crude or natural state about 30 separate minerals from which a great number of mineral products may be manufactured or refined. The list of minerals and direct mineral products of Kentucky is as follows: (1) Abrasives; (2) Aragonite (Ky. Onyx); (3) Artificial Gas; (4) Asphalt Rock; (5) Barite; (6) Calcite; (7) Carbon Black; (8) Cement; (9) Clay Products (Pottery, Tile, Brick, etc.); (10) Coal (Bituminous and Cannel); (11) Coke (Beehive and By-product); (12) Copper; (13) Fluorspar; (14) Gravel; (15) Gypsum; (16) Iron; (17) Lead; (18) Lime; (19) Marble; (20) Mica; (21) Mineral Fertilizer; (22) Mineral Waters; (23) Natural Gas; (24) Ochre; (25) Oil Shale; (26) Petroleum; (27) Phosphate Rock; (28) Potash; (29) Salt; (30) Sand; (31) Silver; (32) Stone; and (33) Zinc.

Of these several minerals Copper, Gypsum, Mica and Potash occur in such a small quantity, or so rarely, as to be of no commercial importance, and therefore are of scientific interest only. A number of Kentucky's minerals, though occurring in large amounts, are not operated except in a very small way; hence the production is of little or no consequence, and will not be considered here. Included in this list are Abrasives, Aragonite (Ky. Onyx), Calcite, Iron, Marble, Ochre, Oil Shale and Salt. Of these, there is an opportunity now to develop on a much

larger scale and at a profit, Abrasives, Aragonite, Calcite, Marble and Building Stones. Kentucky iron ores, while occurring in large quantity and widely distributed, are very low grade and cannot now compete successfully with the Mesabi and Birmingham ores. Some newly discovered hematites in McCreary County may prove the exception to this rule. Kentucky (Devonian) oil shale is one of the largest and richest mineral resources of the State, though at the present low price of crude oil, and the infancy of the shale industry, the immediate development of this resource is not apprehended. The salt resources of Kentucky are not large, and rock salt in commercial quantities is unknown, but it is certain that in certain districts, notably Leitchfield, good semi-artesian brines in very large quantity may be secured.

The following minerals are operated in commercial quantity, and their production coupled with agriculture affords the principal revenue of this State. This list includes Artificial Gas, Asphalt Rock, Barite, Carbon Black, Cement, Clay (and Shale), Coal, Coke, Fluorspar, Lead, Lime, Mineral Waters, Natural Gas, Natural Gas Gasoline, Petroleum, Phosphate Rock, Sand and Gravel, Stone, Tar, and Zinc.

The three minerals having the largest production and value in the State of Kentucky for the years 1918-1920 are in order, coal, petroleum, and fluorspar. As a national producer, Kentucky was, in 1920, fifth in the production of coal, eighth in oil, and second in fluorspar in the whole United States. The production figures of these minerals with their totals is given below. These minerals aggregate in value for this short period of 3 years a total of $401,251,701.

TABLE I.

PRODUCTION OF COAL, PETROLEUM, AND FLUORSPAR IN KENTUCKY, 1918, 1919, 1920.

Coal	Production—Tons	Value	Total Number of Tons	Total Value
1918	31,530,442	$94,591,326		
1919	30,036,061	73,891,049		
1920	38,892,044	159,457,380	100,458,547	$327,939,755
Petroleum	Production—Bbls.	Value		
1918	4,306,893	$11,128,421		
1919	9,226,473	24,459,017		
1920	8,546,027	33,525,210		$69,112,648
	22,079,393 bbls.			
Fluorspar	Production—Tons	Value		
1918	87,604	$2,069,185		
1919	32,386	883,171		
1920	46,091	1,246,942	166,081	$4,199,298
Grand Totals			100,624,628	$401,251,701

The real importance and size of the coal, petroleum, and fluorspar industries in the State of Kentucky as compared to those of all other mineral industries of this State may be seen in the following table, where total values are contrasted.

The statement showing the entire mineral production of Kentucky for the three years, 1918, 1919 and 1920, insofar as it has been possible to complete it, is given herewith.

TABLE III.

1.	Artificial Gas	Production—M. Cu. Ft.	Value	Average Price
	1918	4,279,853	$202,914.00	$0.05*
	1919			
	1920			
2.	Asphalt Rock	Production—Tons	Value	Average Price
	1918	3,194	$30,343.00	$9.50
	1919	32,050	304,475.00	9.50
	1920	58,507	555,816.50	9.50
3.	Barytes	Production—Short Tons	Value	Average Price
	1918			$4.90 (?)
	1919	5,435	$36,408.00	6.70
	1920			
4.	Carbon Black (Natural Gas)	Production—Lbs.	Value	Average Price
	1918	1,600,000	$256,000.00	$0.16**
	1919	2,922,274	244,726.00	0.08-3/10
	1920	1,468,182***	308,318.22	0.21
5.	Cement	Production—Bbls.	Value	Average Price
	1918	536,491	$698,385.60	$1.60
	1919	630,000	1,077,300.00	1.71
	1920			
6.	Clay Products	Production—Brick, Tile, Pottery, Fire Clay	Value	Average Price
	1918		$6,172,554.00	
	1919			
	1920			
7.	Coal	Production—Tons	Value	Average Price
	1918	31,530,442	$94,591,326.00	$3.00
	1919	30,036,061	73,891,049.00	2.46
	1920	38,892,044	159,457,380.00	4.12
8.	Coke (Beehive & By-product)	Production—Short Tons	Value	Average Price
	1918	818,785	$4,455,995.00	$5.44+
	1919			
	1920			
9.	Fluorspar	Production—Tons	Value	Average Price
	1918	87,604	$2,069,185.00	$23.62
	1919	32,386	883,171.00	27.27
	1920	46,091	1,246,942.00	27.05

*Per M. cu. ft.
**Per pound.
***Production estimated.

		Production—Short Tons	Value	Average Price
10. Lead				
	1918	185	$26,270.00	$0.077
	1919	86	9,976.00	.058*
	1920	122	20,008.00	.082*
		Production—Tons	Value	Average Price
11. Lime				
	1918	1,884	$16,258.92	08.63
	1919	988	9,275.00	9.38
	1920	1,757	18,063.00	10.28
		Production—Gals.	Value	Average Price
12. Mineral Waters				
	1918	255,852	$41,997.00	$0.16
	1919	213,436	37,876.00	.17
	1920	256,959	39,600.00	.15
		Production—M. Cu. Ft.	Value	Average Price
13 Natural Gas				
	1918	3,022,439	$334,583.99	$0.1107**
	1919	3,942,000	390,258.00	.099
	1920	3,497,000	354,595.80	.1014
		Production—Gals.	Value	Average Price
14. Natural Gas Gasoline				
	1918	3,330,986	$660,108.00	$0.198
	1919	5,136,326	1,144,746.00	.223
	1920			
		Production—Bbls.	Value	Average Price
15. Petroleum				
	1918	4,306,893	$11,128,421.00	$2.58
	1919	9,226,473	24,459,017.00	2.65
	1920	8,546,027	33,525,210.00	3.92
		Production—Long Tons	Value	Average Price
16. Phosphate*** Rock				
	1918			
	1919			
	1920			
		Production—Tons	Value	Average Price
17. Sand & Gravel				
	1918	818,471	$557,548.00	$0.68+
	1919	1,151,297	744,073.00	.646
	1920	1,637,618	1,047,770.00	.64+
		Production—Short Tons	Value	Average Price
18. Stone				
	1918	988,875	$970,494.00	$0.98+
	1919	1,215,330	1,447,352.00	.653
	1920			
		Production—Gals.	Value	Average Price
19. Tar				
	1918	124,628	$5,995.00	$0.048
	1919			
	1920			

*Per pound.
**Per M. cu. ft.
***Data could not be secured.

20. Zinc	Production—Short Tons	Value	Average Price
1918	315	$57,330.00	$0.08*
1919	36	5,040.00	.07
1920			

While the value of the total mineral production in Kentucky at the present is probably somewhat in excess of $200,000,000 per annum as shown herein, this amount represents only about one-fifth of the amount of mineral development that this State is capable of sustaining. The exploitation of the mineral resources of Kentucky is much behind that of the adjoining States which have mineral resources of a similar value. Lack of good base maps has held back mineral development in Kentucky.

*Per pound.

PERCENTAGE OF COMMERCIAL DEPOSITS OF KENTUCKY MINERALS NOW DEVELOPED.*

Crude Minerals and Crude Mineral Products	Estimated Percentage of Deposits Now Being Operated**
1. Abrasives	5%
2. Aragonite	5%
3. Artificial gas	10%
4. Asphalt Rock	5%
5. Barite	30%
6. Calcite	20%
7. Carbon black	15%
8. Cement	10%
9. Clay products	20%
10. Coal (Bituminous and Cannel)	35%
11. Coke (Bee-hive & By-products)	25%
12. Fluorspar	75%
13. Gravel	10%
14. Lead	15%
15. Lime	5%
16. Marble	0%
17. Mineral Fertilizers	10%
18. Mineral Waters	10%
19. Natural Gas	25%

*The low grade iron ore deposits of Kentucky, widely distributed and of immense quantity, are not included in this list, since they are not at the present time able to compete commercially with the Michigan and Alabama ores.

**Exact determination of the percentage of development of the various mineral resources of Kentucky is impossible at present, due to the inadequacy of funds available for this work under State appropriation to the Kentucky Geological Survey.

20.	Ochre	2%
21.	Oil Shale	0%
22.	Petroleum	75%
23.	Phosphate Rock	25%
24.	Sand (moulding, building, glass)	3%
25.	Stone	25%
26.	Zinc	10%
	Total	470%
	Present development of all minerals, general average..	18+

XI

THE REGION ABOUT FRANKFORT.

By Willard Rouse Jillson.
Director and State Geologist.

INTRODUCTION.

Located on the Kentucky River in the southern central part of Franklin County, and in north central Kentucky, Frankfort* for 130 years the capital of the State, early attained and has continuously maintained an importance in the affairs of this Commonwealth considerably beyond that of other cities of its size. The corporation boundaries are included within 38° 11′ and 38° 13′ north latitude; 84° 51′ 30″ and 84° 53′ 30″ west

THE BEAUTIFUL KENTUCKY RIVER.
The view is a characteristic one near Frankfort looking up stream just below Cedar Run.

*Population 9,805, census 1920.

longitude. In an air line Frankfort is 49 miles almost due east of Louisville, and 22.5 miles northwest of Lexington. With these cities it is connected by an excellent, state-maintained, rock asphalt and surface treated, automobile highway—The Midland Trail. Other less important macadam roads leading from Frankfort are: the Lawrenceburg Pike (south), the Devil's Hollow Pike (west), the Bald Knob Pike (northwest), the Owenton Pike (northeast), and the Glenn's Creek Pike (southeast). The city is served by four railways: the Louisville and Nashville, the Chesapeake and Ohio, and the Frankfort and Cincinnati Railroads, and the Kentucky Traction and Terminal Company, an interurban trolley connecting Frankfort with Lexington.

Divided by the Kentucky River, which is spanned between St. Clair and Bridge Streets by a steel arched bridge erected in 1893, and rebuilt in 1921, the principal divisions of the City have come to be known as North and South Frankfort. The former is the older in point of settlement and is largely devoted to retail shops and manufacturing industries, while the latter is of comparatively recent expansion, and given over almost entirely to residential purposes. The old State House and its separate east wing are located in North Frankfort, facing Broadway, while the old Governor's Mansion and the State Reformatory, facing High Street, occupy several blocks from Ann Street on the west to Thomas street and the F. and C. Railroad yard on the east. The new Capitol and the new Governor's Mansion are situated south of the Kentucky River at the head of Capitol Avenue, the central subjects of a broad landscaped terrace. Within the Frankfort corporation limits, but west of the river and north of Benson Creek, is located Bell Point, while Leestown, just north of Fort Hill, and Thorn Hill, a mile northeast of the same physical promontory, are sparsely populated suburbs dependent upon the city.

PHYSIOGRAPHY.

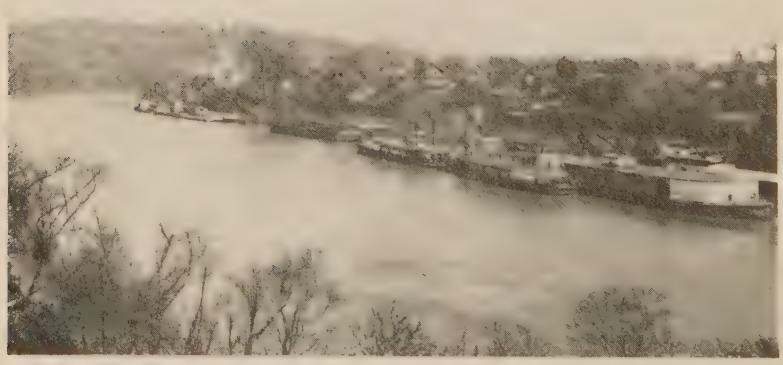
The natural surroundings of Frankfort, the high, forest-clad hills, the craggy limestone precipices, the gracefully winding Kentucky River, describing a perfect letter "S" within the corporation, are the most picturesque and delightful of any city in the State. The country pikes leading out of the town have a

WOODED HILLS AND LIMESTONE CLIFFS.

The view is down stream (West) from the St. Clair Street Bridge and shows well the contrast of lowland and upland about Frankfort. Long tows of rafted logs are frequently to be seen.

quaint southern and scenic charm that the traveler will not fail to note and appreciate. In the spring the dainty red bud in bloom on Buttimer's and the South Frankfort hills is a visual treat long to be remembered, while the solid green of the midsummer shade trees along quiet old-fashioned residential streets, and the variegated russets and reds of the autumnal period, draped by the inspired hand of nature over the gray crags above the river and the bold cliffs of Fort Hill, afford natural contrasts as pleasing as they are diversified.

Back of the scenic and picturesque which serves to delight the eye of the traveler in Frankfort is a story of physical changes in the topography and drainage of the region that is not generally known. The city proper is located on the bottom lands of a double meander in the gorge of the Kentucky River. Elevations of 500 feet above the sea level are common in these lowlands, while the broad undulating plateau immediately surrounding attains an elevation of 750 feet and upwards. There is thus produced a physical relief in the Frankfort vicinity of approxi-



RIVER INDUSTRIES AT FRANKFORT.

The improvement of the Kentucky River has resulted in the development of a considerable water traffic, in both North and South Frankfort. South Frankfort on the right is situated on the inside of an oil meander of the Kentucky River.

mately 250 feet. Fort Hill, singularly isolated, and 785 feet high, challenges attention at the first glance. Though it will not be suspected, there is hidden in the correct solution of the origin of this giant outlier of bedded Ordovician limestone, the key to the physiography of the whole Frankfort region.

The caprices of a river, ever a fruitful study for those interested in the earth's sculpture, are responsible for the peculiar topographic conditions found at Frankfort. Could we but go back to middle Tertiary times and stand somewhere on the State cemetery hill, the view would be quite different from that which greets the sightseer of today. There almost at our very feet, slowly winding its meandering course towards the sea, we should find the Kentucky River, the central drainage artery of a great broad valley plain. A river, then much the same in size as the Kentucky of today, though sluggish because of its base leveled condition, the scene would have been quite different topographically from that which greeted the eye of the first explorer, or the present day sightseer for there were no cliffs or scarps at that time, and the deep gorge of the Kentucky River as we know it now was yet to be carved. The general figure of the channel, however, was much the same, except that the river itself turned sharply to the east just below the Devil's Hollow, and found its course on through the flat bottoms towards what is now known as Thorn Hill. Benson Creek, which came down close to the Kentucky River at Bell Point, did not enter it here, but continued on and found its mouth at this early time just northeast of Leestown, and at a later period, below Lock No. 4, and just west of the present site of the O. F. C. Distillery.

Events transpiring during the latter part of the Tertiary period in the nature of a great structural uplift of central and eastern Kentucky served to rejuvenate the old Kentucky River and gradually brought about the present character of the topography for which the region is widely noted. Simultaneously with the uplift of the Frankfort area, the Kentucky River set about its newly appointed task of entrenching itself into the more or less soluble Ordovician limestone. Later it took up the work of lateral expansion of its gorge. The whole region of South Frankfort has at times remote, been the changing bed of

A PEEP OUT THROUGH THE WILLOWS.
There is much that is picturesque about Frankfort. The gorge of the Kentucky River is well defined here as one looks upstream across the L. & N. Railroad Bridge.

the river, which from the time prior to its entrenchment had made a sharp turn to the northeast over North Frankfort. In the course of lateral expansion of the gorge by the growth of sharply curved meanders, a very pronounced bend came to be developed in the Kentucky River bed in the region of North Frankfort known as "Craw." This meander extending outward laterally to the northwest, met the strong and somewhat comparable yet smaller meander of Benson Creek, extending itself outward to the southeast. The ultimate result of these migrations was the removal by erosion and solution of the narrow isthmus of limestone connecting Buttimer's Hill with Fort Hill.

With a limestone natural bridge existing perhaps for a while under which the high tides of the Kentucky River first found passage into the lower reaches of ancient Benson Creek, as is now the case at points on the Cumberland River in Kentucky, the normal and main body of the river continued to flow for a

time in its old course around through the low flat bottoms of the Thorn Hill meander. At this time the bed of the Kentucky River was slightly less than 500 feet, as is shown by the present excavations for the new Frankfort drainage canal in the abandoned river bottoms of the Thorn Hill meander, where residual limestone clays have been encountered at the very shallow depth of four feet. The old course of the Kentucky River through the Thorn Hill meander as well as the general topography and geography of the Frankfort region is clearly indicated on the new topographic map of Frankfort and vicinity. This map which is here presented for the first time, has but recently been completed by the U. S. Geological Survey and the Kentucky Geological Survey working in co-operation. The map shows elevations in standard brown contours, culture and geographic boundaries in black, streams in blue and the Midland Trail in red. The scale is 1-24,000.

In the course of time the limestone barrier connecting Buttimer's Hill with Fort Hill was entirely removed, and seeking the shorter course, the river appropriated the lower portion of Benson Creek and gave up forever the old Thorn Hill meander. In making this change, it assumed the somewhat accelerated gradient of lower Benson Creek, with the result that shoals and rapids were developed between the present mouth of Benson Creek and what is now Lock No. 4. Prior to its improvement by the Federal Government, the fall in this portion of the Kentucky River was seven feet. At this same time "Fish Trap Island" over half a mile in length extended down the river from the mouth of Benson Creek.*

It was the occurrence of the pronounced shoals in the vicinity of Leestown in an otherwise ordinarily deep river that brought the buffalo to this point for a crossing. These same shoals stopped the McAfee-Taylor party en route up the river in July, 1773, and induced them to explore and complete a six hundred acre survey of the present site of Frankfort.** Subsequently it was the well defined buffalo wallow or trace which brought the early explorers to this point in Kentucky, and resulted in

*History of Franklin County Johnson, 1912, p. 35.
**History of Franklin County, Johnson, 1912, p. 28.

FEDERAL DAM AT LOCK No. 4.
It was just below this point that the Leestown Shoals occurred which determined the early settlement of the Frankfort Region. Fort Hill is in the background.

the settlement of Leestown long before Frankfort as a townsite was seriously considered.

The first settlers of Frankfort found the topography of the bottom lands of what is now the northern part of this city much different than it is today. All of that section known as "Craw" was a low swale, which annually filled with back-water and vegetable rubbish brought down by the floods of the Kentucky River. This was the re-entrant of the old channel which today has been filled in upwards of 50 feet with all kinds of city rubbish and refuse. It is said that while drilling a water well on the "Gas House" plot some 50 years ago at a depth of 60 feet, the dirt auger used, encountered and brought to the surface a large portion of an old walnut log, thereby indicating that the scour of the old river had at this point at least, reached considerable depth.

In the early days in the vicinity of what is now the east end of the L. and N. railroad station, and extending slightly southwestward beneath where now stand the Frankfort Motor Com-

pany garage and Manford's Livery Stable, was a deep crevice in the Ordovician limestone, through which a considerable portion of the river waters passed in a "cut off" to the north. This "cut off" connected the river from its present location in the vicinity of Manford's stable with the opposite side of the North Frankfort meander in the vicinity of the State Reformatory. Old residents of Frankfort well remember the trace of this limestone fissure, and during recent excavations for building purposes, an old log pen which had been built during early times to keep cattle from falling into an open sink-hole of this fissure, was discovered buried at a considerable depth. During periods of low water this fissure has been measured at a number of places, and found to be from 5 to 7 feet in width.

In reflecting on the changes in the course of the Kentucky River in the vicinity of Frankfort, it is interesting to recall the disastrous Kentucky River flood of 1883 which filled as a backwater the Leestown branch to the State Reformatory, where it joined a similar eddy which had advanced over "Craw" and made a typical island out of Fort Hill.* In doing this the river demonstrated its claim to the broad Thorn Hill bottoms and repeated before the eyes of thousands of astonished and alarmed spectators the physiographical history of the Frankfort region. A further point of interest is that today the city of Frankfort is endeavoring to reconstruct in the valley filled Kentucky River bottoms leading from the city through the Thorn Hill meander, a new drainage channel, which it is hoped will be an improvement over the natural embarrassed drainage of this section, and redirect the waters of this lowland region more rapidly to the river below Leestown in the same direction which the old river once pursued.

GEOLOGY.

The geology of the Frankfort section is relatively simple. The section which is lower Ordovician is one of orderly sequence and almost horizontally deposed. It has been worked over by a number of geologists, Dr. David Dale Owen in 1857 having prepared the first report. Each of the workers in this region has contributed to the knowledge of the local geology. All of the beds exposed are limestone or shaly limestone, the lowest being what is

* History of Franklin County, Johnson, 1912, p. 30.

THE GREAT ORDOVICIAN OUTLIER, "FORT HILL."
The Kentucky River is here flowing to the left (North) through the Benson cut off. Originally it turned to the right (East) close under the Fort Hill cliffs and completed the Thorn Hill meander.

known as Tyrone limestone, which is of Stone's River (Black River) age. The uppermost is the Cynthiana formation, found on the top of Fort Hill. Higher beds, not exposed in the immediate vicinity of Frankfort, may be found in all directions, somewhat removed from the townsite and the river. The geological section from the Curdsville to the Perryville inclusive is of Trenton age. The several limestone formations shown in superimposed order and maximum local thickness are as follows:*

GEOLOGICAL SECTION AT FRANKFORT, KY.

Champlainian	Cynthiana (basal portion only exposed)	60
	Perryville	25
	Flanagan	45
	Bigby	75
	Wilmore	80
	Hermitage	45
	Curdsville	10
	Tyrone (upper portion only exposed)	60
	Total of all maximum thickness	**400

The attitude of the beds of limestone in the Frankfort region appears to be nearly horizontal, though the regional dip is slightly to the northwest. Local dips of very small degree and continuance may be found in most any direction. There are no mineral veins of commercial importance intersecting the area so far as known, though small fragments of calcite, barite and fluorspar have been found very close to the city. The limestones outcropping in the bluffs of the gorge are used for road making and building construction purposes with little discrimination as to their occurrence. The best building stone of the section, however, is the white, hard Tyrone ("Birdseye"), a silicious limestone, which has received the trade name of "Kentucky River Marble." It was used in the construction of the old State House in 1828, and in much of the business and residential building construction of from 50 to 70 years ago. Today it finds its chief use in ornamental construction purposes for residences, retaining walls, etc.

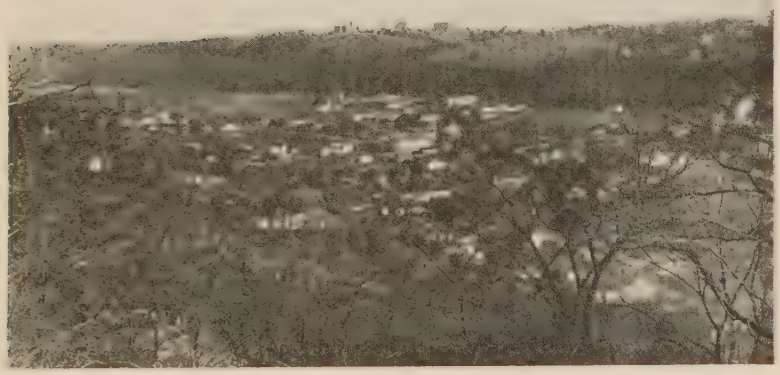
*Geology of Franklin County, Ky. Miller. Ky. Geol. Survey, Series IV, 1914, p. 19. (Adapted.)

**A measurement of the total section at Frankfort shows considerably less than 400 feet due to the thinning of some members.

PANORAMIC VIEW OF FRANKFORT TOPOGRAPHY.

The view is from the Louisville road near the new Capitol. On the right is the present course of the Kentucky River, on the left the old course, in the center Fort Hill.

In summarizing the geologic history of the Frankfort area, it is interesting to note that the final abandonment of the old channel from Thorn Hill to the river occurred in comparatively recent times, geologically speaking. Though this time cannot be accurately expressed in years, it was probably not less than 5 or more than 15 thousand years ago. Following the abandonment of the old Thorn Hill meander, the river continued to degrade its channel, while the old bottoms became a back-water or swale. This continued for a long time, while the amount of erosional deposit from the hills surrounding and the back-water silt slowly grew in thickness. Yet today this recent deposit is relatively very small, totaling less than 10 feet at the most.



THE ABANDONED THORN HILL MEANDER.
The view is from Fort Hill looking southeast across the old river bottoms new Frankfort.

The location of Frankfort as a city was brought about by the somewhat uncommon geological phenomena of deeply incised meander channel abandonment. Had this not occurred, there would never have been enough room in the gorge of the Kentucky River for the location of this city. But for this factor the important shoals from Benson Creek to Leestown would not have been developed, the buffalo would not have driven their

trace across it, and the exploring white man would not have found it his most convenient place of fording on his wilderness pilgrimages across the State. The settlement of Frankfort is more recent than that of Lexington and Louisville in point of years, but the geologic causes which made Frankfort possible are older than history.

The End.

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

KENTUCKY GEOLOGICAL SURVEY
WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

KENTUCKY
(FRANKLIN COUNTY)
FRANKFORT AND VICINITY

84°53′ 52′ 84°51′

38°13′

OWENTON PIKE
LOCK NO. 4
Leestown
Thorn Hill
Bell Point
BALD KNOB PIKE
KENTUCKY RIVER
LOUISVILLE & N. R.R.
ELECTRIC R.R.
FORT HILL
ELECTRIC R.R.
CINCINNATI
AND
FRANKFORT
OLD CAPITOL
PEN
BM 511
BM 512
TRAIL TO LEXINGTON
MIDLAND R.R.
678 ELECTRIC
FRANKFORT
GLENN CREEK CEMETERY
Buttimer Hill
DEVILS HOLLOW PIKE
South Frankfort
TRAIL
MIDLAND TO LOUISVILLE
NEW CAPITOL
LAWRENCEBURG PIKE
PIKE
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1921

Scale 24 000
0 ½ 1 Mile
0 ½ 1 Kilometer

Contour interval 20 feet.
Datum is mean sea level.

38°11′ 84°53′ 52′ 84°51′ 38°11′

ENGRAVED 1921 BY U.S.G.S.

Polyconic projection. North American datum.

C.H. Birdseye, Chief Topographic Engineer.
W.H. Herron, Division Topographic Engineer.
Topography by R.L. Harrison.
Control by B.H. Yoakum, J.R. Ellis, and C.H. Semper.
Surveyed in 1921.

SURVEYED IN COOPERATION WITH THE STATE OF KENTUCKY.

FRANKFORT AND VICINITY.
Edition of 1921.

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